PROJECTILES AND RIFLED CANNON.

SYSTEMS OF PROJECTILES AND RIFLING,

WITH

PRACTICAL SUGGESTIONS FOR THEIR IMPROVEMENT,

AS EMBRACED IN A

REPORT TO THE CHIEF OF ORDNANCE, U.S.A.

BY

CAPTAIN JOHN G. BUTLER,

ORDNANCE CORPS, U.S.A.

WITH APPENDIX,

CONTAINING THE REPORT OF THE BOARD ON EXPERIMENTAL RIFLED GUNS, ON THE PROOF OF AN EIGHT-INCH CONVERTED RIFLE.

ILLUSTRATED BY THIRTY-SIX LITHOGRAPHIC PLATES.

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1875.

At the suggestion of friends, and with the consent of the Chief of Ordnance, I have decided to place the subjoined report in the hands of the publisher. It is not expected that the views therein enunciated will carry conviction to every reader. The facts given are regarded as important; the theories—whether original or adopted—as plausible; while the importance of the subject, I am fully conscious, justifies far more able treatment than it has received in the following pages.

I avail myself of this opportunity to express my obligations to Colonel T. G. Baylor, commanding Fort Monroe Arsenal, for much useful advice and information during an official stay of three years at his post.

B.

LIST OF TABLES.

I. Showing the irregularities of Powder-pressures due to the Balloting and Wedging of Rifle Projectiles of large calibre, from Records of experimental Firing from 1866 to 1871.
II. Comparative Velocity and Accuracy of Breech and Muzzle Loading Field Projectiles.
III. Proposed System of Rifling for Muzzle-loading Guns.
IV. Showing the Velocity of a Projectile at different points of the bore of an 8-inch Rifle, and the circumstances attending Rotation in the different characters of "Pitch."
V. Comparative Pitch of Rifling, adopted in English, Russian, Prussian, and American Guns of different Calibres.
VI. Tabulated Time, Velocity, and Pressure Curves, based upon Experiments in England by the "Committee on Explosives," with an 8-inch Rifle and four varieties of Powder.
VII. Weights of Projectiles of different Calibres; showing the inconsistency of present prevailing Standard Weights for large Calibres.
VIII. Showing the Comparative Weights of Projectiles in different countries and a proposed Standard.
IX. Comparative Velocities of Breech and Muzzle Loading Projectiles with Grained Powder.
X. Details of Proposed Rifling for Breech-loading Guns.
XI. Partial List of English Rifles burst or disabled at "Home-Stations."
XII. Proposed Plans of Rifling for Expansive Stud Projectiles.
XIII. A brief summary of results obtained up to November 1, 1873, with the new Projectile and Experimental Powders. From Reports of Major and Brevet-Col. T. G. Baylor, Commanding Fort Monroe Arsenal.
XIV. Record of Firing at Fort Monroe Arsenal with Improved Powder and Projectiles.
XV. Comparative Energy and Penetration in Iron Plates of Projectile of various Weights and Calibres.

APPENDIX.

XVI. Extracts from Reports of Experimental Firing with different Lots of Hexagonal Powder, from an 8-inch Rifle at Fort Monroe.
No. 1. Record of Firings for Endurance with an 8-inch Experimental Rifle, from October 24 to December 23 (inclusive), 1874, at Sandy Hook, New York Harbor.
No. 2. Record of Firings with 8-inch Experimental Rifle continued.
No. 3. Relative diameters of Bore of cast-iron body of 10-inch Gun and of wrought-iron Tube for insertion therein, at different points of their cylindrical length.
No. 4. Table of Enlargements of 8-inch Converted Rifle, No. 1.
No. 5. Showing the Relative Energies of the 8-inch United States M. L. Rifle (converted), and the 8-inch English M. L. Rifle of 9 tons, at distances up to 1,800 yards.
No. 6. Relative Effectiveness of a 10-inch Smooth-bore, and the same gun converted into an 8-inch Rifle.
No. 7. Record of Target-Firing with 8-inch Converted Rifle No. 1, at Sandy Hook, New York Harbor, December 22, 1874. Distance of Target from Muzzle of Gun, one mile.

LIST OF PLATES.

PART FIRST.

I. Soft and Hard Sabots. Balloting and Stripping Projectile.
II. Illustration of Balloting. Windage.
III. Proposed 3.5-inch Field Shrapnel and Percussion Fuze.
IV. Target Records of 3-inch Rifle at 820 and 1,500 yards.
V. Proposed 2.5-inch or 2.7-inch Shrapnel for Mountain Service.
VI. Proposed 2.7-inch Shell for Mountain Service.
VII. Proposed Rifling for Expansive System, in connection with Table III.
VIII. Siege Projectile with Projecting Base.
IX. Ten-inch Projectile of 400 pounds as fired at Fort Monroe, Sabot screwed on.
X. Twelve-inch Projectile of 700 pounds with Steel-Head, Sabot locked on.
XI. Proposed Projectile for a 15-inch Rifle.
XII. Proposed Projectile for a Rifled Mortar and Concussion Fuze.
XIII. Proposed Double-bearing Expansive Projectile.
XIV. Different forms of Double-lipped Sabots.

PART SECOND.

XV. Proposed Breech-loading Field Projectile, Double-bearing.
XVI. Proposed Breech-loading Non-expansive Projectile, Double-bearing.
XVII. Proposed Breech-loading Projectile, Centering Segments and Fuze.
XVIII. Proposed Breech-loading Shrapnel. Long and Double Chamber.
XIX. Proposed Breech-loading Projectiles with Long and Short Chambers.

PART THIRD.

XX. Illustration of Woolwich Groove. Wooden and Papier-maché Sabots.
XXI. Proposed 12-inch Expansive Stud Projectile, Double-row.
XXII. Flat-headed 15-inch Stud Projectile, Single-row.
XXIII. Expansive Stud Projectile for "Light" 15-inch Rifle. Proposed in 1870.
XXIV. English, Prussian, and American Field Shrapnel.

TIME AND PERCUSSION FUZES.

XXV. Figure I. Combination Time, Percussion, and Friction Fuze.
Figure II. Combination Time and Percussion Fuze.
XXVI. Figure I. Combination Time and Percussion Fuze.
Figure II. Percussion Fuze.
XXVII. Illustration of Relative Effects of Time and Percussion Fuzes.
XXVIII. Figure I. Concussion-Fuze applied to base of Projectile.
Figure II. Percussion-Fuze applied to base of Projectile.

ADDENDA TO PART FIRST.

XXIX. Record of Target-Firing with 8-inch Rifle at 1,500 Yards.
XXX. Diagram illustrating Formula for Penetration in Iron Plates.
XXXI. "Recovered" 12-inch Projectile of 700 pounds. Fired with 100 pounds of powder.
XXXII. Illustration of Effects of Hollow-casting. Proposed Experiment.
XXXIII. Full Dimensions of Sabots for all Calibres of Projectiles.

APPENDIX.

XXXIV. (I.) Ten-inch Rodman S. B. Gun, converted into an 8-inch M. L. Rifle.
XXXV. (II.) Ten-inch Barbette Carriage, altered for 8-inch Rifle, with Friction Strap.
XXXVI. (V.) Hexagonal-grained Powder.
(VII.) Erosion in bore of 8-inch Converted Rifle after 513 Rounds.

ERRATA.

Page 17, Bottom—for *elongated* projectiles, read *expansive* projectiles.
Page 22, Top—for *Fig. I.*, *Plate I.*, read *Fig. II.*, *Plate I.*
Page 27, Bottom—for *Plate I.*, *Fig. III.*, read *Plate II.*, *Fig. I.*
Page 28, Middle—for *is it likely*, read *is it not likely.*
Page 31, Middle—for *Plate IV.*, read *Plate VI.*
Page 64, 13th line—for *d*, *b*, read *a*, *c*.
Page 66, Top—for *Plate XVII.*, read *Plate XVIII.*
Page 67, Bottom—for *Plate XIV.*, read *Plate XIX.*
Page 68, Middle—for *c*, *d*, read *c*, *a*.
Page 111, Top—for *s*, read *b*.

CONTENTS.

LETTER TO THE CHIEF OF ORDNANCE.

Growing mistrust of our own system of rifling and projectiles, 9—The importance of the subject, 10—Unsettled condition of the problem, 10—Conditions essential to a perfect system, 11—Proposed order of treating the subject, 12.

PART FIRST.

THE EXPANSIVE SYSTEM.

General defects of projectiles heretofore used, 14—Attempts to remedy existing evils, 16—Wedging of expansive projectiles, 16—Balloting of expansive projectiles, 17—Causes and effects of balloting, 18—Records of past experimental firing with heavy rifles, 20—Principal dangers to guns from misconduct of projectiles, 24—The poor character of our past record, 24—Proposed remedy, 25—Description of the proposed projectile and its operation, 25—Advantages of the projectile, 26—Remedy for balloting, 26—General advantages of windage, 31—Success of the double-lipped expansive projectile, 31—Relative accuracy of breech and muzzle loading rifles, 32—Relative velocity of breech and muzzle loading projectiles, 33—Increase of charge for field-guns recommended, 34—Proposed "mountain-service" rifles of 2.5-inch or 2.7-inch calibre, 35—Rifling, and proposed modification, 35—The grooves, 35—The pitch, 37—Character and ultimate value of pitch, 38—Direct and angular velocity of projectiles in bore of guns, 39—The "compromise pitch," 39—Distribution of work of rotation along the grooves, 40—Comparative pitch of rifling in different countries, 41—Rapidity of the English pitch, 43—Time, velocity, and pressure curves. English experiments, 44—Attachment of sabots to projectiles, 45—Double-bearing projectiles, 47—Weight of projectiles, 48—Inconsistency of practice, 48—Standard weights in different countries, 50—Formula for proposed standard, 50—Experiments with 10-inch Rodman rifle, and risks incurred, 52—Our system, as improved, the most perfect known, 52.

PART SECOND.

THE COMPRESSIVE SYSTEM.

General character of projectiles of the compressive class, 54—Prismatic powder and "lead-coated" projectiles, 54—Defects of the compressive system of lead-coated shot, 55—Strains due to closing of windage, fouling, and compression, 56—Reduction of velocity by compression and fouling, 57—Increasing pitch impracticable with lead-coated projectiles, 60—Liability to injury in store, handling, and transportation, 60—Closing of windage ; further objections, 61—The use of molten metal impracticable, 62—Stripping of lead-coated projectiles, 62—Reduced capacity for bursting charge, 62—"Leading" of grooves and increased friction, 63—Proposed system of breech-loading projectiles and rifling, 63—Description and operation of double-bearing projectile, 64—Non-expansive breech-loading projectile, 66—The single-bearing breech-loading projectile and short-chamber, 66—Details of proposed rifling for breech-loading guns, 69—Probable advantages of the new over the old system, under the following heads: 1. Controlling windage. 2. Forcing. 3. Fouling and leading. 4. Friction. 5. Initial velocity. 6. Choice of pitch. 7. Injury in rough handling. 8. Centering. 9. Heavy charges. 10. Use of canister. 11. Scoring and guttering. 12. Fouling and cleaning of chamber. 13. Compactness. 14. Powder-pressures. 15. Capacity. 16. Use of time-fuzes. 17. Molten metal, 69 to 75.

PART THIRD.

THE FLANGED SYSTEM.

The adoption of such a system for experimental guns deprecated, 75—Projectiles comprised under this system, 75—Brief reference to experiments in England, 75—The "Woolwich" system of rifling and projectiles, 76—Severity of the system upon the gun. A vicious system, 77—English criticisms of the stud system, 77—Extract from the *Mechanics' Magazine.* "Irregular pressures," 78—Extract from *Engineering.* Weakness of projectiles, 78—Paper of Commander Dawson, R.N. Necessity for a new system, 79—Causes of failure of the Woolwich system, 79—Irregular

flight of projectiles, and their erratic course in the bore of the gun, 80—"Wobbling of Woolwich shell," *Mechanics' Magazine*, 80—A most unmechanical contrivance, 81—The silent testimony of recovered projectiles, 81—Scoring of projectiles and "hammering" action in the gun, 82—Severity of strains "too much even for Woolwich guns," 84—*Broad Arrow* and other authorities, 84—"French rifling in British guns," *Engineering*, 84—"Errors of judgment" and a "cloud of partisanship," 85—"Powder-pressures" from English magazine, 86—"Wriggling" projectiles and high and irregular powder-pressures, 87—Want of due relation between pressure and velocity, 88—Inapplicability of the increasing pitch to studded projectiles, 90—Experiments with a single row of studs, 91—The argument in favor of "long bearing" fallacious, 93—The "Cemetery of Suicides" at Woolwich, 93—System proposed in 1870, 95—Mr. Wiard's proposition and its impracticability, 96—Proposed double-bearing stud-projectile, 97—Rifling for single and double bearing projectiles, 97—Operation of the proposed projectile, 98—The single row of studs and the increasing pitch, 100.

CAST-IRON RIFLES OF LARGE CALIBRE.

The opinion of the late General Rodman as to the necessity for procuring a projectile "certain in its operation," 101—Public confidence lessened in cast iron. A hasty verdict, 101—An important question only half solved, 102—Confidence in our muzzle-loading system, 102—Résumé of the record of our cast-iron guns, 103—Propriety of procuring heavy experimental rifles of cast iron, 105—A proper programme for proof should be fixed and rigidly adhered to, 106—Importance of testing heavy rifles of cast iron, 106.

TIME AND PERCUSSION FUZES.

Adoption of the percussion-fuze for field-shrapnel recommended, 108—Description of different fuzes submitted, and objects to be attained, 109—Essential qualifications of a good time-fuze, 111—Operation of time and percussion-fuzes described, 112—Relative efficiency of time and percussion fuzes, 112—Superiority of the percussion-fuze, 112—The combination-fuze, 113—Recommendation, 114.

ADDENDA TO PART FIRST.

Experiments at Fort Monroe up to date Oct. 1873, 115—An unblemished record with the new projectile, 115—Experimental record, 116—Foreign armaments, 117—Extracts from Ordnance Notes, XVIII., 117—Experimental firing at Fort Monroe with improved powder and projectiles, 118—The 400-pound 10-inch projectiles again, and fulfilmeut of prediction respecting them, 121—Injury sustained by the gun, 121—Weight of projectiles, 122—Comparative energy and penetration in iron plates of projectiles of different weights and calibres, 124—Fulfilment of necessary conditions by the new projectile, 125—Modification of the Rodman system of gun-construction, 128—Opportunity for a crucial test of the merits of cast iron for heavy rifles, 130.

APPENDIX.

Various guns recommended by the "Board on Heavy Rifled Ordnance in 1872," 131—The introduction of Hexagonal-grained powder, 132—Experiments at Fort Monroe with a view to the determination of proper standards, 132—Success of Expansive breech-loading projectiles, 134—The rifling of the Moffatt, the Sutcliffe, and the Thompson breech-loading guns, 134—Systems of conversions, 135—Summary of results at Sandy Hook, 136—A record without a parallel, 138.

REPORT OF THE BOARD ON EXPERIMENTAL RIFLED GUNS.

Detail for and orders convening the Board, 139—Recommendations of Board on Heavy Rifled Ordnance, and letter of Colonel Crispin, 140—Description of the Gun tested at Sandy Hook, 141—The Carriage, Recoil-check, and Elevating Apparatus, 142—Description of Hexagonal powder used in proof, 143—Projectiles employed, 144—Action of the projectiles, 144—Experiments and tests, 145—Accuracy, 145—Effects on the gun, 146—Easy action of the projectiles on the bore, 146—Effects on the carriage, 147—Velocities and pressures, 147—Strength of the system, 148—Effects against armor-plates, 150—Recommendations of the Board, 150.

REPORT OF THE CHIEF OF ORDNANCE.

MESSAGE OF THE PRESIDENT OF THE UNITED STATES.

PROJECTILES AND RIFLED CANNON.

FORT MONROE ARSENAL, November, 1872.

TO THE CHIEF OF ORDNANCE, WASHINGTON, D. C.:

SIR: I have from time to time, during the past few years, submitted for your consideration drawings of projectiles, fuses, etc., and plans of rifling, accompanied with brief explanations and reports, reserving the privilege of submitting more complete reports in the future.

The recent appropriation by Congress of funds for the procurement of certain experimental rifles of large calibre will afford an opportunity of testing the merits of some of the different systems of gun-construction, both breech and muzzle loading. Having determined upon the nature of the guns, it will be necessary to decide upon the character of the rifling and upon the projectiles to be used in proof. It would be obviously unwise to introduce into the programme for the proof of these guns any strange or experimental features where it can be avoided, and this fact alone furnishes a good reason for not departing from our expansive system of rifling and projectiles for the proposed muzzle-loading guns. As I am well aware, however, of a growing mistrust of our own system, based on past practice and the poor character of the projectiles now in service, and of a tendency to favor the stud system, based upon published (and often partisan) accounts of extensive experiments in France and England, I have thought the present opportunity a good one for presenting in detail my views on a

subject to which I have devoted long and close attention, trusting that they may prove of some interest and value.

The "battle of the guns" is not yet fought out; but, while the advocates of the different systems of gun-construction have been conducting their conflict on paper and at the proof-butt, it is extraordinary that the importance of the kindred subject of *projectiles* has not been more fully recognized, and that more marked improvement has not been made in this direction. It seems rather to have been a settled conviction in the minds of military engineers that the subjects of rifling and projectiles were about exhausted; that no new system could be designed; and that material improvement in any existing system was scarcely to be looked for. Hence all their energies seem to have been directed toward the construction of guns strong enough to bid defiance to the severe tests to which the least objectionable of the existing systems of rifling might subject them. As a consequence, we find England's "magnificent guns" ruined in a few rounds by a vicious system of rifling and projectiles; Krupp's expensive ordnance subjected to ordeals, lighter, it is true, but still unnecessarily severe, in spite of the adoption of Rodman's "prismatic powder"; other countries in a "sea of doubts"; while at home many of our officers have lost entire confidence in cast iron for heavy ordnance, and demand at once stronger guns, without giving a thought to their rifling or to the projectiles to be fired from them, as though these were questions already settled, or it mattered little what system be adopted.

I maintain that no less important than the question of gun-construction are the questions of rifling and projectiles—nay, more important to-day; for whatever be the respective merits of various gun-constructions, most of them would be found abundantly strong, if their strength were only properly economized.

The "decided failure" of the "French-Woolwich" system of rifling, the poor practice of the French, Austrian, and other systems, and the undeveloped state of our own, have recently attracted the attention of the military world in a marked degree to this subject. "It is a curious feature of the times," says the *Mechanics' Magazine*, "that a controversy which was presumed to be finally and satisfactorily settled seven years since, by conclusive results derived from an extensive competition between heavy guns rifled on various systems, should be now cropping up to perplex the naval and military artillerist of the day."

Assuming that an entirely unobjectionable projectile may be constructed, and admitting so undeniable a fact as that a poor gun, firing such projectiles, may outlive a good gun, served with inferior projectiles, the true importance of the subject must be admitted. It is, of course, no vain assertion to state that the best

heavy rifle ever constructed could be burst or ruined at the first fire by a projectile especially adapted to effect such a purpose, and that the same gun might be *endangered* by certain forms of projectiles defective in principle or construction, while a gun in many respects inferior might give a good record, if every projectile fired from it behaved uniformly and well.

The following are some of the conditions especially desirable in any system of rifling, all which must be fulfilled by a projectile that is claimed to be perfect:

1. Accuracy.

2. Perfect rotation ("taking the grooves"), due to the twist, as indicated on the recovered projectile by proper marks of the rifling on the rotating device.

3. Steadiness or smoothness of flight, as indicated by smoothness of sound.

4. Absolute non-liability of the projectile to *jam* within the gun, either in loading or firing.

5. Non-liability to strip either within the gun or during flight, even with the heaviest charges.

6. Must not injure the gun by breaking, nor produce unnecessary torsional strains of any kind by wedging, etc.

7. Entire absence of balloting.

8. Maximum capacity for bursting charge.

9. Uniform and moderate pressures.

10. Uniform and high velocities.

11. Uniform and good ranges.

12. Absolutely safe to fire over the heads of our own troops—a contingency constantly arising in both land and sea service.

13. So strong and safe in principle as to allow a wide margin for all errors of manufacture, and even inferiority of materials.

14. Non-liability to injury in store, handling, or transportation.

15. Not too expensive.

If an inferior quality of powder be employed, the *pressures*, *velocities*, and *ranges* will be irregular, and the *accuracy* correspondingly impaired, but none of the remaining foregoing conditions should be affected in the slightest.

Some of the above requirements being enumerated by Major Owen in his treatise on "Modern Artillery," he remarks: "In many systems of rifling one or more of these conditions have been sacrificed to some extent, doubtless to secure a closer compliance with others thought to be of greater importance or of easier attainment." No system, indeed, has ever proved an exception to this rule, and the sacrifice of useful and essential conditions incurred by some systems is something marvellous.

How far the problem—given a gun, to find a perfect projectile and system of rifling—has been from a successful or satisfactory solution can be fully appreciated by those who have made the subject a specialty, or who have had a fair glimpse at the records of past experience.

"Naval and military journals," says an English magazine, "are beginning to complain that six years of ceaseless improvement (?) have failed to provide our heavy guns with suitable projectiles. The unexplained and extraordinary pressure of 66 tons to the square inch in the powder-chamber of the 35-ton gun, instead of the usual 30 tons due to the charge, and consequent splitting of the steel lining, have given point to these complaints."

From every source, indeed, amidst much boasting of the superiority of this system or that, we hear more or less complaint of dangerous and unsatisfactory projectiles, or, at best, of serious defects and greatly desired improvement in this direction.

That safe, reliable, and in every respect efficient projectiles might be had, has long been my earnest conviction, and the marked success which has attended recent experiments at Fort Monroe induces the belief that, whatever the improvements of the future, we have now at command a system worthy of every confidence;—one which, while thoroughly efficient in every particular, will yet never prove treacherous. It is in the confidence inspired by such a hope that I am induced to lay before you the accompanying papers on this subject.

In my treatment of the question I propose to assemble the different forms of rifling and projectiles under three general systems, as follows:

1. The Expansive System, embracing all projectiles which, in loading, are inserted in the gun without respect to the rifling, but which "take the grooves" by the action of the gases of discharge upon a device or feature of the projectile, which is readily expanded thereby into the grooves of the gun.

2. The Compressive System, embracing all projectiles which are loaded in a chamber, and then forced by the action of the powder through the bore of the gun, the diameter of which across the lands is less than the superior diameter of the projectile. All projectiles for breech-loading guns have heretofore been of this class.

3. The Flanged System, embracing all projectiles upon the cylindrical portion of which are projections which, in loading, are intended to be inserted into corresponding grooves in the bore of the gun. These projections may be studs or buttons, ribs or flanges; grooved shot being nothing more than flanged shot with wide flanges.

In each of these systems I shall have one or more projectiles to propose, also modifying in each case the rifling; which proposed projectiles, in my judg-

ment, will go far toward supplying long-felt necessities in the service of rifled ordnance. Of each of these systems it is my purpose to reveal the principal defects, and in each to suggest what I trust may prove practical remedies.

Very respectfully,

Your obedient servant,

JOHN G. BUTLER,

Lieutenant of Ordnance.

PART FIRST.

THE EXPANSIVE SYSTEM.

This class of projectiles has been so extensively and, it may be said, exclusively used in the United States that in many countries it is known as the American system.

Most of the European governments, after more or less experiment with expansive projectiles fitted with lead sabots, seem to have considered the system as unreliable and in no way suited to the requirements of service. Confined, as their trials were, principally to the lead sabot, this unfavorable verdict is not surprising.

In our own country, four years of war and the necessity for rifle projectiles stimulated the inventive talent of the country, and a great variety of projectiles were urged upon the Government. Many of these failed absolutely; others secured a partial success in preliminary trials, and were afterward condemned in the field; a few only were found to stand the test of service, and of these not one gave entire satisfaction.

Although it may be necessary to discuss at some length two kinds of the more prominent projectiles in our service—namely, those with the lead or soft-metal base and those with the brass ring—yet it is less my purpose to criticise individual projectiles of the expansive class than to point out the general defects of the system, and to suggest remedies which may place this system in the van of all others for general efficiency. Of the few expansive projectiles which have heretofore been used and tested, and which have seemed each in turn to give some promise of success when applied to large calibres, it may be remarked briefly:

1. Where the sabot is of lead or "soft metal," windage is apt to be entirely closed. The lead may strip or be forced over the projectile, and balloting or wedging be induced, followed by a train of evils.

2. Those projectiles similar in pattern to the above, but having sabots of copper or brass, cup-shaped on the bottom of the projectile, seem to suffer from

the violence of the explosion within the cup, which is apt to be broken thereby, or, if not broken, to be unevenly "set up." It might be difficult at times to assign full reasons why these projectiles fail, but that their failure has been frequent is a simple matter of record.

3. Those forms where a leaden jacket is forced out by the action of the discharge upon a wedge or key have small capacity as shell, no strength as shot, strip easily, and are open to many other objections, while for large calibres they are worse than worthless.

4. Equally objectionable are those cases where a concave or a convex disk is flattened against the base of the projectile, or in addition is provided with a flange or key which is driven by the discharge upon the tapered base of the projectile. The use of such a projectile is equivalent to introducing a wedge into the gun, and it is obvious that the principle is a vicious one. In such a projectile the sabot is not *expanded* into the grooves, but is wedged, "upset," or "crowded" into them. The metal of the sabot between the lands of the gun on the one side, and the unyielding body of the shot on the other, is compressed and actually caused to flow to the right and left into the adjacent grooves. If this metal is brass or copper, the severity of the strain can be imagined. In fact, the area of the disk which is operated upon by the force of explosion must be at least one-half or one-third the area of the base of the projectile, and hence in the larger calibres a force of from one to several millions of pounds will be operating upon a powerful wedge, and bringing upon the walls of the gun a bursting strain entirely auxiliary to that of the powder-gases as indicated by the pressure-gauge. Apart from this, to obtain just the right materials and just the mathematical proportions which will ensure the correct "taking of the grooves" are points so nice as to leave absolutely no margin for errors of workmanship or defects in material; whereas, in dealing with forces so tremendous as those involved in the explosion of gunpowder, a *wide margin* should be allowed for all such errors or accidents, and, if any such should occur, it should be rendered impossible for them to cause injury to the gun. Stripping, also, has always been found a notable feature of such projectiles.

5. In all those forms of sabots or rings intended to be expanded by the entrance of the gases of discharge between them and the iron body of the projectile proper, the powerful effort of the gases to expand the sabot into the rifling tends violently to strip it from the projectile, and in fact the sabot must become in great part detached from the prejectile before it can "take the grooves." The prying up of the hard sabot in this manner frequently results in breaking off wedge-shaped pieces of the projectile from its base, causing it to wedge or "jam" within the bore.

Some of the more serious defects developed in these projectiles in the field were:

1. Failure to "take the grooves."

2. "Wobbling," "tumbling," or irregular flights, and inaccuracy from various causes.

3. Stripping of the rotating device or sabot from the projectile, killing or wounding our own men, over whose heads it was necessary to fire.

4. Damage in transportation and deterioration in store.

5. Small interior capacity for bursting charge.

The above defects, together with others more clearly traceable to errors of manufacture, obtained to a greater or less degree in all the projectiles employed; and of the four or five which were of necessity retained in the service, only one or two varieties were considered to hold out any promise of success in guns of large calibre.

During experiments at Fort Monroe, it appeared so obvious to the late General Rodman that the enormous pressures so frequently recorded in the proof of our cast-iron rifles were clearly traceable to the projectiles, that he was led to think it possible to obtain better results by the use of plain iron projectiles having grooves cut through their entire cylindrical length, which fitted over corresponding lands in the gun. No success, however, attended these experiments. The pressures ranged very high, both in 8-inch and 12-inch guns; the former burst at the eightieth round, and the practice with this projectile was discontinued in the latter gun. The experiment subsequently tried of edging the ribs on the shot with brass "gibs" was attended with no better results, while the cost of the projectile was greatly increased.

Various other kinds of projectiles were tried from time to time, but none gave satisfaction, and the Ordnance Department seemed justified in falling back to first principles, and continuing experiments with projectiles having lead sabots. Extended trials with these projectiles establish clearly, I think, that although they have been made as perfect as any projectile with a lead sabot can be, nevertheless, first, at their best they are uncertain and dangerous, especially for large calibres; and, second, adequate weights of powder and projectiles cannot be employed.

Two dangers especially to be guarded against in expansive projectiles are wedging and balloting.

Wedging is a common fault of all projectiles fitted with hard sabots, to expand which into the grooves of the gun it is necessary for the gases of discharge to separate from the shot. This feature is illustrated in Fig. II., Plate I. Here the expansion of the sabot into the rifling is accomplished by the entrance of the gases between the sabot and the base of the projectile. It will be seen at once

Fig. I.

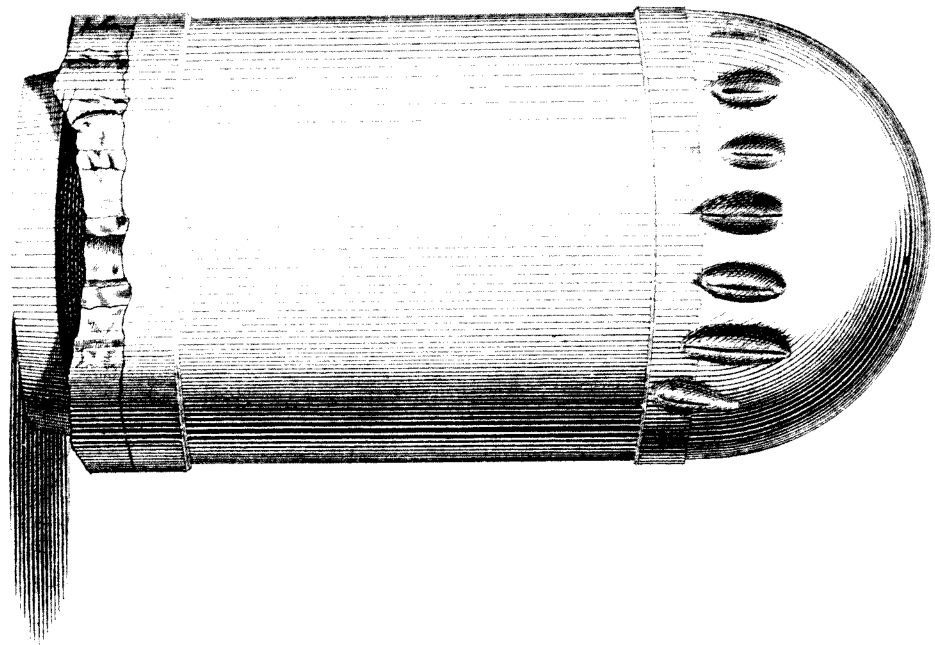
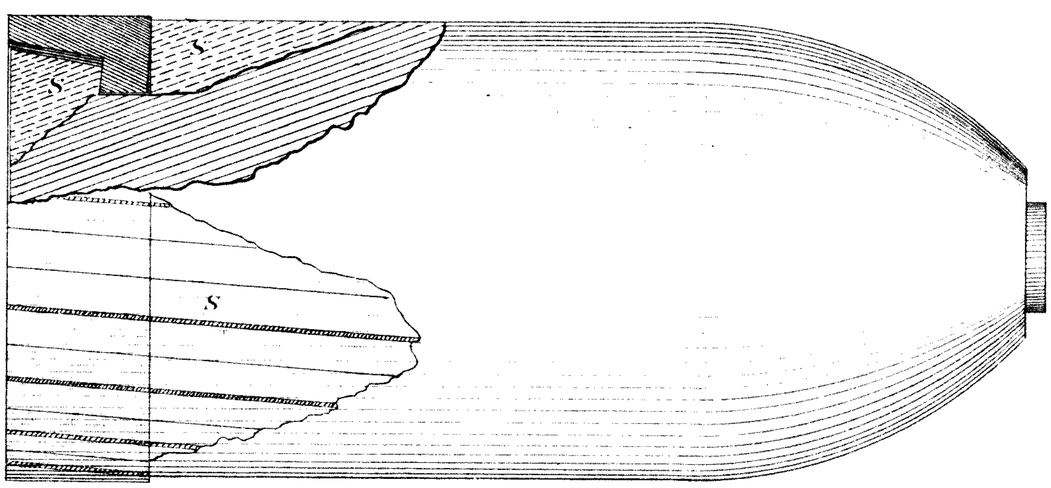


Fig. II.



D. Van Nostrand, Publisher, New York.

that the tendency is to strip the ring from the shot, while the tendency to pry off the wedge-shaped pieces, *s*, *s*′, is too apparent to require explanation. These iron wedges are almost invariably found to be deeply impressed by the lands of the gun, and the accompanying pressures are frequently very great. The larger the calibre of the gun, the more liable is this difficulty to occur, and the premature bursting of several heavy rifles may be correctly attributed to this cause.

In the case of the soft-sabot projectile, not only is the soft metal forced into the rifling, but it is likewise squeezed over the body of the shot, closing up all windage, and practically wedging the projectile into the bore of the gun in a manner scarcely less objectionable than that just described. This detention of the shot materially augments the pressure; and if at this moment the shot could be freed from unnatural restraint, the velocity might be increased. Unfortunately, however, the higher the pressure, the tighter the wedging and the greater the friction, and we frequently find a *reduced* velocity the accompaniment of an enormous pressure.

Other forms of sabots are intentionally so constructed as to take the grooves by the wedging of the sabot over the base of the shot. This system I deem highly objectionable at the outset.

Next to wedging or the temporary lodgment of a projectile in the bore of a gun, balloting is an evil to be avoided, and is undoubtedly a source of great injury to the gun, not only of itself, but because it frequently leads to a complication of difficulties, such as stripping, wedging, breaking, etc. The balloting of spherical projectiles is well understood, and, as the number and intensity of the ballots or rebounds is constantly changing, we have an ever-varying angle of departure of the shot, and consequent inaccuracy. Of the intensity of this balloting it is difficult to speak with any definiteness. If the material of the gun be soft, such as bronze or wrought iron, the effects are speedily manifested in the enlarged and battered surface of the bore. In guns of harder material, such as steel and cast iron, this effect is less appreciable, but it is impossible to say what effect the repeated and violent blows of balloting projectiles may have upon the harder materials of gun-construction.*

I have never seen any special allusion to the balloting of elongated projectiles, certainly none prior to my report on the subject in the spring of 1870,† and yet I am convinced that it is a matter for much more serious consideration than in the case of smooth-bores. Balloting is especially liable to obtain in soft-sabot

* It is my belief that, by the use of a proper form of sabot, balloting in smooth-bore guns could be prevented; and if this be found to be the case, the sabot should never be omitted. See Plate XX., Fig. 11.

† We are beginning to hear a good deal now of the "wriggling" of English projectiles.

projectiles, where windage is completely closed, and the projectile is centred only at its base.

To illustrate the cause of balloting, its bad effects and injurious tendencies, reference is had to Fig. I., Plate II., which represents a soft-sabot projectile with exaggerated windage. The first effect of the discharge is to expand the sabot, *s s*, into the grooves of the gun, shutting off all windage; and, if we assume this expansion to be uniform, the rear of the projectile will be centred—*i.e.*, the centre of figure of the base of the shot will be placed in the axis, F F, of the bore; but F F is also the resultant of the forces of discharge, and, while the rear of the shot is centred, the front part is not so, but rests upon the bottom of the bore at T. Now, the line of direction, F F, passing through C, and above the centre of gravity, G, of the projectile, the point, R, of the latter is forced upon the bottom of the bore at T; from this point it rebounds, and the point R′ strikes the bore at T′. From this point the projectile is thrown off with increased violence against the point T″, and so on throughout the bore each blow is more violent than the preceding one, owing to the increasing velocity of the projectile and the impetus gained from its previous contact with the walls of the gun.

That balloting under such circumstances is extremely violent cannot, I think, be doubted; but it would be difficult to form any estimate of its force. If we assume the projectile to be 12 inches in diameter, with a windage of 0.10 inch, and acted upon by a pressure of 60,000 pounds per square inch, then, knowing the length of the shot, it might be found that the pressure of R upon T would be 14,000 pounds. What is a pressure at T, however, becomes a *blow* at T′, and, as has been stated, these blows increase in violence with each successive ballot, but in a ratio not easy to determine. Even any estimated pressure at T must be incorrect, as the projectile would doubtless commence to ballot before the maximum pressure was attained. This, however, would in no way diminish the effect of the subsequent rebounds. Although the force of these blows cannot be absolutely calculated, an idea of their intensity may be formed from the effect produced. Numbers of these projectiles have been recovered which have borne indelibly the marks of the lands upon their hard surfaces, and in some instances deep impressions of the rifling have been left upon the front end of hard iron projectiles.

The effect of balloting, however, is by no means limited to such injury as the bore of the gun may sustain from it; for it naturally leads to other evils, such as lodging, wedging, upsetting, etc.—results which have proved disastrous to many guns. Balloting is, in effect, a lodgment or binding of the projectile; it is an interruption to the free egress of the projectile from the bore, and hence practi-

cally amounts to an obstruction. It is illustrated in every day's experience, in the binding of bureau-drawers, or of windows which, from "wobbling," come even to a dead-lock as we attempt to raise or lower them; also in the destructive vibration or "chattering" of loosely-fitting machinery, where it is far more economical to increase the friction by too tight a fit than to assemble the parts too loosely; yet the most rapid and violent movements of machinery are but feeble in comparison with the intense action of a projectile in the bore of a gun.

The resistance which balloting opposes to the free passage of the projectile through the bore of the gun naturally augments the powder-pressure behind it, whereby not only is the violence of balloting increased, but the sabot is expanded more tightly than ever against the bore, sealing effectually every possible avenue of escape for the gases; a pressure is attained which forces the sabot over the body of the projectile, wedging the latter in the bore, and doubling up the pressure again, so that, if the gun survive the ordeal, the projectile is found stripped of its sabot and deeply marked by the lands of the gun. With projectiles so acting, the mildest of powders will become "brutal" and the finest gun-constructions must succumb.

Such results do not, of course, invariably obtain; on the contrary, a majority of the projectiles are found with their sabots intact and a fair impression of the rifling upon them. The sabot has been partly sheared away, and, though partly closed up again, a slight escape of gas has occurred, everything has happened to go well, and a maximum pressure from any irregularity of the powder has fortunately been avoided. Balloting may, nevertheless, have obtained—a fact frequently proved by the erratic flight of the projectile; for, its last rebound occurring as it is leaving the gun, the front end of the shot is no longer restrained by the walls of the gun, and hence a great tendency to turn end over end, in spite of the rotation due to the twist of the gun. The result is a compromise of motions anything but satisfactory. I have observed numbers of such projectiles which, when recovered from the butt, have shown every indication of having taken the rifling thoroughly, and yet, when fired at moderate angles for range or target, have yielded a large percentage of "irregular" flights. Balloting here has obtained, not with sufficient violence to injure the gun or projectile, or even to augment materially the pressure, but just enough to cause unsteadiness of flight.

In support of the foregoing views I have given on the following page a table compiled from official records of firing with three 8-inch, two 10-inch, and three 12-inch rifles. Glancing down the second column, it will be seen that in nearly every instance two or more consecutive rounds have been selected for comparison with each other.

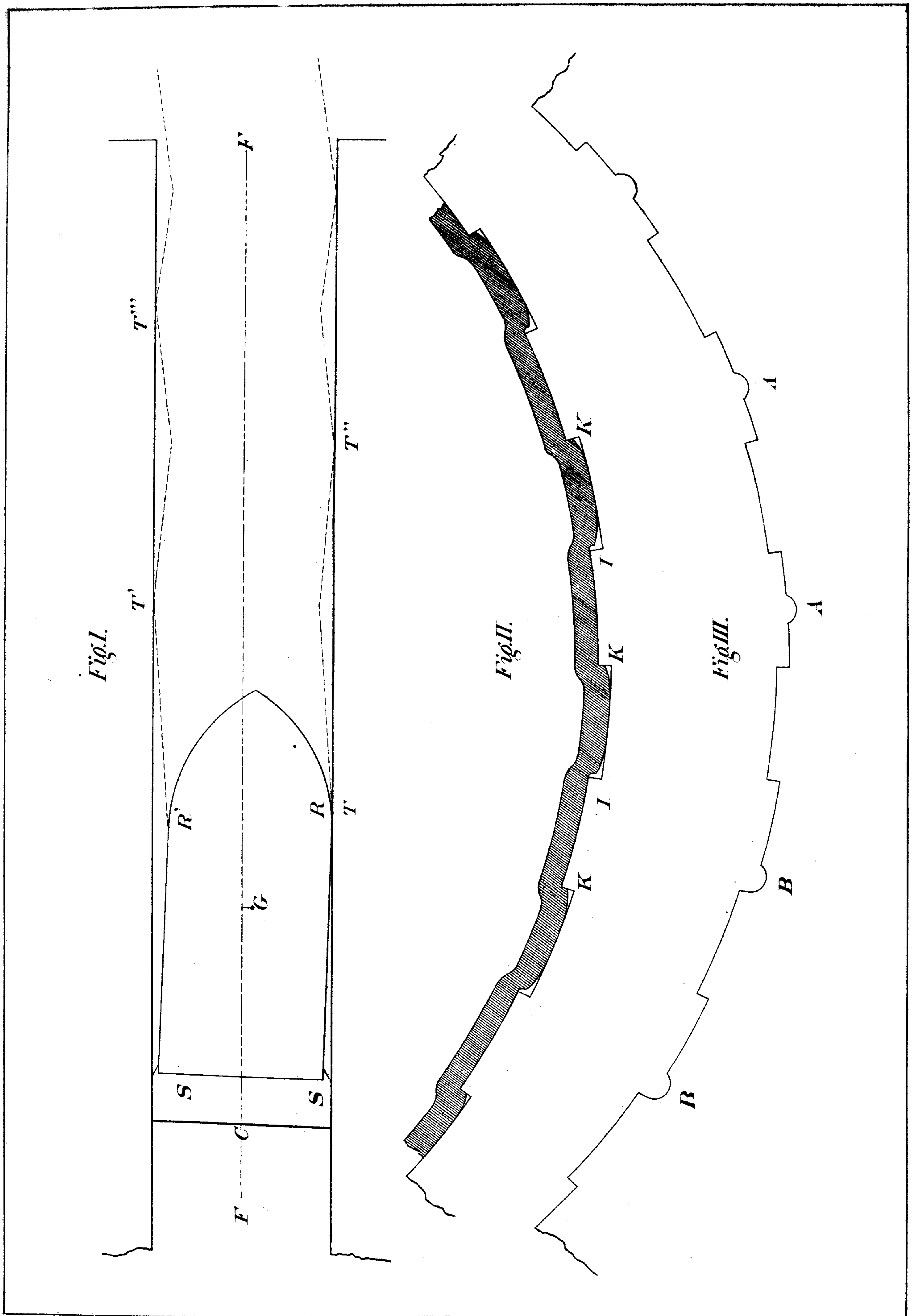
TABLE I.

Showing the irregularities of powder-pressure due to the balloting and wedging of rifle projectiles of large calibre. From records of experimental firing, from 1866 *to* 1871.

Example.	No. of round from gun.	Calibre.	Powder.		Projectile.		Pressure.	Velocity.	REMARKS.
			Kind.	Wt.	Kind.	Wt.			
1	1046	8 in.	Cannon.	14½	Lead Sabot.	148	80,000		
2	1047	"	do	14½	do	148	150,000		Gun burst. { Sabot stripped. Impression of lands on iron body of the projectile.
3	747	8 in.	Lens.	15	do	150	100,000	1,254	Soft metal forced over windage.
4	748	"	do	10	do	150	77,000	1,076	Soft metal forced over windage.
5	755	"	do	25	do	150	100,000	1,286	
6	756	"	do	22	do	150	31,000	Lost.	
7	215	"	Cannon.	15	do	154	41,000	1,285	Sabot took grooves well.
8	216	"	do	15	do	150	41,000	Lost.	Sabot took grooves well.
9	224	"	do	14	do	148	100,000	1,092	Sabot stripped badly.
10	1	8 in.	do	15	Brass Sabot.	149	64,000	Lost.	
11	2	"	do	15	do	149	98,000	1,240	
12	3	"	do	15	do	148	100,000	817	Gun burst. { Projectile broke and wedged in bore as shown in Fig. I., Plate I.
13	12	10 in.	Mam.	25	do	292	73,000	1,284	
14	18	"	do	30	do	292	27,000	1,155	
15	1	10 in.	do	40	Lead Sabot.	300	36,000	1,128	
16	2	"	do	40	do	300	88,000	1,280	
17	25	12 in.	do	55	do	420	23,000		
18	30	"	do	55	do	531	88,000		Gun burst. Projectile stripped.
19	4	12 in.	do	51½	do	646	32,000	1,088	
20	5	"	do	51½	do	603	34,000	Lost.	
21	6	"	do	70	do	683	200,000	924	Sabot stripped.
22	7	"	do	70	do	658	200,000	1,088	Sabot stripped. } Deep impression of the rifling on the iron body of these projectiles.
23	8	"	do	70	do	609	150,000	1,007	Sabot stripped.
24	20	"	do	60	do	600	69,000	1,193	
25	27	"	Cake.	71	do	600	98,000	641	Gun burst. { Sabot stripped. Deep impression of rifling on shot lands mashed in gun.
26	1	12 in.	Mam.	64	do	624	240,000		Sabot stripped. Shot lost in water.
27	2	"	do	64	do	623	79,000		

The contrast in pressures and velocities might, indeed, have been made more glaring by selecting the smallest of a series always for comparison with the largest; but the table is probably more instructive as it is, and exhibits forcibly the dangers to which our heavy rifles have been exposed. A projectile of moderate weight, for example, is fired with a very moderate charge, and the pressures and velocities for one or two rounds bear something of a proper relation to one another. Suddenly, without any apparent reason, the same kind and weight of projectile, fired with the same charge from the same "lot" of powder, comes from the gun stripped of its sabot, scored and abraded by the rifling, and tumbles through the target screens with a greatly reduced velocity, while the pressure indicated is perhaps beyond the capacity of the gauge to record.

Plate II.



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The foregoing table comprises but a few of many such "anomalies" to be found in the records of past experimental firing with expanding projectiles. Precisely the same irregularity of pressures and want of correspondence between pressures and velocities is now the subject of much complaint in English experiments with the Woolwich (stud) system, while the record of the plane-grooved projectile is no better.

In some cases in the foregoing table, the projectiles not having been recovered for examination, their condition after firing is not known. By glancing down the column of "remarks," however, it will be found that any marked irregularity or misconduct on the part of the projectile is almost invariably accompanied by an enormous pressure, and perchance a burst gun. The first gun on the list would appear to have given a most creditable endurance, and, although the great majority of projectiles fired from it were less than 130 pounds, and were fired with charges generally of ten and twelve pounds, yet as the projectiles were mostly experimental, and behaved badly, very many high pressures were recorded. Even 148 pounds must be conceded a very light shot for an 8-inch rifle, and, fired with only $14\frac{1}{2}$ pounds of No. 5 powder, we had no right to expect the enormous pressure (150,000 pounds) recorded when the gun burst; the stripped and mutilated projectile, however (fortunately recovered), explains the mystery of an enormous strain and a burst gun—results which otherwise would doubtless have been pronounced "anomalous."

In the third and fourth examples furnished the report simply states that "the soft metal was forced over the projectile"; this, however, is sufficient to account for the disproportionate pressures obtained. In the fifth and sixth examples there are no remarks, and one velocity was unfortunately lost; but we observe that three additional pounds of "lens" or "button" powder has unaccountably (?) quadrupled the pressure. The inference is perfectly reasonable that the projectile behaved properly in the one case, and not so in the other. Examples 7, 8, and 9 are very instructive. We have here two consecutive rounds in which the projectiles behave well; the pressures are within reasonable limits, and the velocity good for the charge. At the next round, however, with less weight of the same powder and projectile, the latter "strips badly"; the pressure is trebled, while the velocity is diminished *two hundred feet.*

Examples 10, 11, and 12 refer to an 8-inch Parrott gun, which, as shown in the table, burst at the third fire. The projectiles had brass sabots, intended to be expanded into the grooves by the entrance of the powder-gases *between* the sabot and the shot. I am certainly not ready to believe that this gun would have burst under the powder-pressure of 100,000 pounds per square inch indicated by the gauge, unless such pressure was long sustained or repeated; but such a

pressure would give 5,000,000 pounds upon the base of the projectile, and this force, acting upon the projectile as a wedge (see Fig. I., Plate I.), would be very apt to open the gun. This same wedging would, of course, diminish the velocity of the shot, as would also the opening of the walls of the gun before the shot had cleared the bore. Accordingly, we find a velocity of 800 feet, when it would be reasonable to expect from such a pressure behind so light a shot a velocity at least double that recorded.

Resuming our inspection of the table, in examples 13 and 14 we have the too common anomaly (?)—the lesser charge with the same weight of projectile giving the vastly larger pressure.

In examples 15 and 16 are given the only rounds which have been fired, until quite lately, from a new 10-inch Rodman rifle. Here will be observed the same extraordinary jump in pressures which has so often obtained in practice without a proportionate increase of velocity.

We now come to the heaviest rifles. The twenty-fifth and thirtieth rounds will do for comparison. At the last round, with a light charge, the projectile, a light one, stripped, and the gun burst under a pressure of 88,000 pounds per square inch. This gun was known as the "Atwater rifle."

Examples 19, 20, 21, 22, 23, 24, and 25 next claim attention. We have here the same old story of stripped and wedging projectiles, of balloting and lodging of a violent description, of tremendous jumps upward in pressures, and downward in velocities, and at last of a burst gun, repeatedly taxed beyond all reason. Observe that in the fourth round from this gun a charge of $51\frac{1}{2}$ pounds of mammoth powder, with a projectile of 646 pounds, gave 32,000 pounds pressure and 1,088 feet velocity. There certainly seemed full justification for an increase in the charge, and accordingly, at the sixth, seventh, and eighth rounds, charges of 70 pounds were employed. As a result, enormous pressures, calculated to exceed 150,000 pounds and 200,000 pounds per square inch, were obtained, and yet the velocities were absolutely *less* by an average of 120 feet than when the pressure was but 32,000 pounds with the lighter charge. Nothing but the balloting and wedging of the projectile could produce this state of things; and if further evidence of the fact were wanting, a glance at the stripped and mutilated projectiles would probably be sufficient.

These tremendous strains proved too much for the gun, and hence numerous well-defined cracks and minute fissures began to appear distinctly in the bottom of the bore, and it was believed that the gun had about reached the limit of its endurance. It was, nevertheless, fired subsequently some twenty rounds, the pressure varying from 37,000 pounds to 88,000 pounds. Five years later it was decided to use this gun in a limited series of experiments with perforated cake

powder, which was confidently expected by the officer in charge to yield very low pressures and but moderate velocities; and, indeed, subsequent trials of 50-pound charges in a 15-inch gun gave pressures scarcely reaching two tons per square inch, being quite uniform and confined between the limits of three and four thousand pounds. The charge employed in the rifle was 70 pounds of cake, with one pound of mammoth, to fill the space about the pressure-plug, and a projectile under 600 pounds weight. The result I have good cause to remember, first, from the striking corroboration afforded of the correctness of a theory of balloting and wedging long entertained; and, second, because a large fragment of the burst gun fell close beside me, where I stood in fancied security behind a heavy smooth-bore. The pressure indicated by the gauge was about 100,000 pounds. The gun burst into nine fragments; the projectile, deeply marked by the rifling near the head, was detained in the bore not only long enough to augment pressure, but for the heat to melt the sabot, the shot then making a sluggish escape, the velocity being but 631 feet. The sabot of the projectile was entirely stripped from it, melted and spattered through the fissures and over the fragments of the yielding gun. Not a fragment of the sabot was recovered; a perfect helix of mashed lands marked the course of the projectile through the bore, and the pressure indicated would no doubt have been vastly greater but for the yielding of the already over-strained gun. In fact, the three previous pressures of 200,000 pounds and 150,000 pounds to the square inch, supplemented by twenty additional rounds, had probably brought the gun close to the limit of its endurance, and its possible bursting at the first subsequent round was anticipated in a letter to the *Army and Navy Journal* scarcely more than twenty-four hours before the actual occurrence of the fact.

We come now to the last two lines of the table, Nos. 26 and 27. These are the only two rounds ever fired from a 12-inch Rodman rifle at Fort Delaware, and the only gun of its class now in service. Unfortunately, there were no facilities for taking velocities. The projectiles were of good weight, but the charges were moderate, and, being of the best available mammoth powder, only moderate pressures were, I presume, anticipated. One projectile chanced to go well; observe that the pressure, although high, is not necessarily dangerous. At the next round, however, the projectile stripped, and we have doubtless the same old story of balloting and wedging, and a pressure, carefully estimated on the Rock Island testing-machine, of 240,000 pounds per square inch.

This lodgment or detention of the projectile by balloting or wedging—a fact which I believe has been satisfactorily proven to have frequently occurred—not only increases directly the strains of the powder-gases, besides exerting more or less power as a wedge, but *sustains* and *prolongs* them, and that, too, through a

longer portion of the bore, until all assistance due to the inertia of the mass of the gun is completely neutralized, and the chances of bursting are thereby and to that extent increased. There can be no doubt, of course, that the natural power of large guns to resist rupture is directly and materially aided by the inertia developed in the great mass of the metal itself, the natural reluctance of such a mass to change its normal condition of rest. Change, therefore, a high, quick pressure of short endurance for one of *equal intensity* but longer duration, and the chances of a burst gun are vastly increased.

It follows, therefore, that by the misconduct of a projectile by balloting, wedging, stripping, etc., the gun is subjected to five principal dangers, any one of which is apt to lead to others, and all of which are *liable* to operate at the same time.

1. An immediate increase of pressure, directly due to the jamming of the projectile.

2. A further increase of pressure from the possible disintegration of the powder, especially in the case of cake or prismatic, and its more rapid combustion under such circumstances.

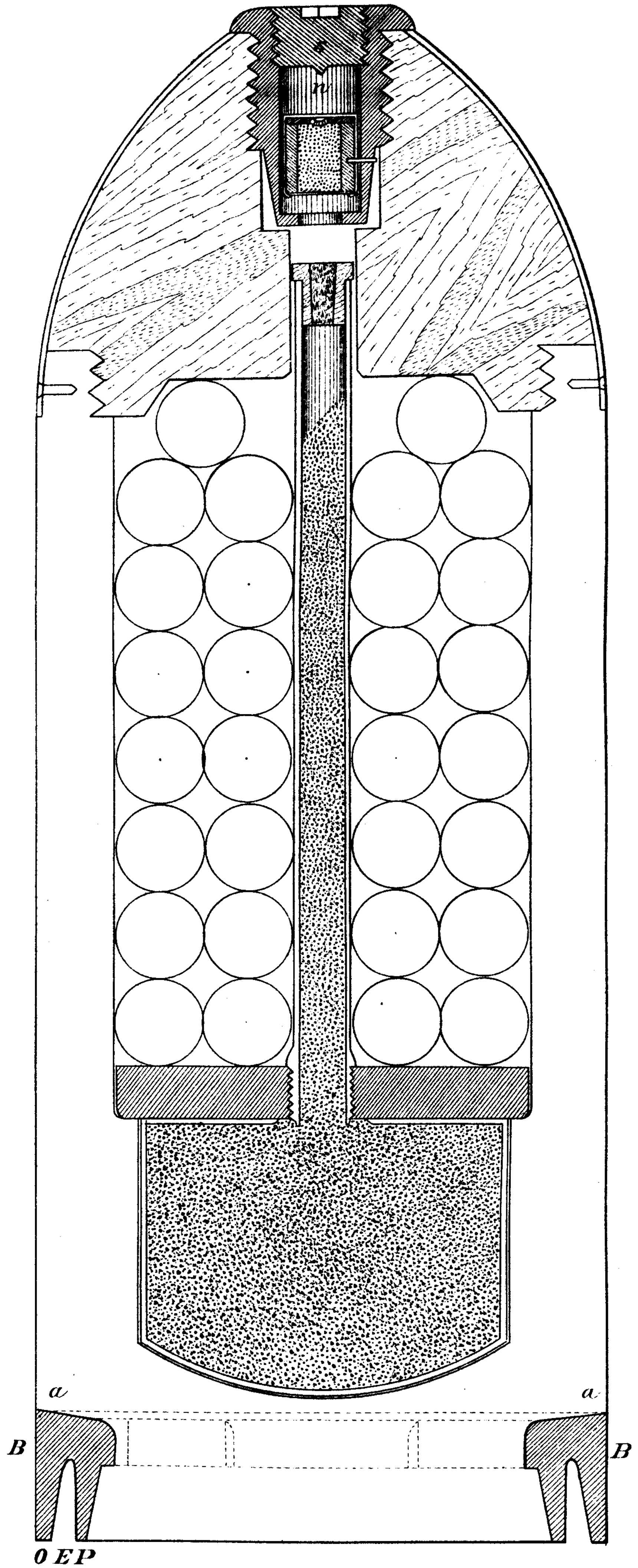
3. The projectile having moved some distance before lodging, the maximum bursting strains are extended through a greater length of bore, and the danger of rupture is further increased with the increased distance of the resultant of these forces from the bottom of the bore.

4. The lodgment of the projectile compels the gun to sustain what is at best perhaps a dangerous pressure, until all assistance derived from the inertia of the mass is nullified.

5. The projectile, operating as a wedge with a pressure of millions of pounds upon its base, tends powerfully to open the gun.

The simplicity of the expanding system strongly recommends it for muzzle-loading guns, and especially for field calibres, where rapid firing is a desideratum. Its advantages, indeed, are numerous and well acknowledged, but the defects of different projectiles of this class have been so many and serious as to more than counterbalance, in the opinion of many, the admitted advantages of the system.

The principal defects which have been conspicuous in field-projectiles of the expansive class are: 1. Failure to take the grooves. 2. Inaccuracy from that and other causes. 3. Stripping. Moreover, in large calibres, as has been explained, are two additional objections—far more serious in large than in small calibres—namely, 1, balloting; and, 2, wedging. When we add to this all the faults arising from errors of manufacture, use of poor material, etc., and bear in mind that all our projectiles have heretofore been light, and have always been fired with small charges, our record is by no means a flattering one.



3.5 in Field Shrapnel
containing 120 lead ½ oz balls - 53 in Diam.

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It is my belief that all these objections and defects may be successfully met and obviated in the system of rifling and projectiles now about to be described. Indeed, without in any degree altering the plans of rifling at present prevailing in our rifled guns, it is believed that admirable results may be obtained, and that the proposed projectile may be successfully fired with almost any form of groove.

Upon Plate III. is shown in full size a 3½-inch field-projectile, that being a calibre now officially adopted in the service.

It will be seen that the rotating device consists of the double-lipped annular band or "sabot," B, attached to the base of the projectile by one of several methods to be described. The narrow cannelure, E, between the upper and lower lips of the sabot, distributes the gases of discharge so evenly that the slightest irregularity in the expansion of the upper lip has never been discovered; whereas in all projectiles which procure expansion by the entrance of the gases between the sabot and the body of the projectile, as also in certain forms of sabots which cover the entire base of the shot, it is frequently found that the sabot is very unevenly set up; *i.e.*, it is forced out more on one side than the other.

In the expansion of the upper lip into the rifling, no matter how violent the pressure (and a test of 100,000 pounds per square inch has been designedly applied), the junction of the sabot and projectile along the line *a a* is always as smooth and perfect as before firing—an advantage which will be specially referred to hereafter. While, however, the upper lip, O, is freely expanded into the grooves of the gun, the lower lip, P, is pressed upon the body of the projectile with an intensity proportionate to the force of discharge, thus not only causing the ring to hug the projectile tightly, but, as a gas-check, preventing the entrance of gas between the ring and the iron body of the projectile. Stripping is thus effectually prevented; whereas, in all projectiles where the gas finds entrance between the sabot and the projectile, there is a violent tendency to strip them apart—a fact too often accomplished.

The expansion of the upper lip being exceedingly limited, owing to the restraint of the bore, the only way this projectile could strip would be to tear off the upper lip in conveying to the projectile the rotation due to the twist. Experiments made to determine this point with 3-inch projectiles weighing 11½ pounds and under pressures of 75,000 lbs. per square inch, showed that a thickness of one-sixteenth of an inch was unaffected by this strain. The grooves of the gun being somewhat rounded, the sabot bore marks of having slipped over the lands, probably toward the muzzle, where the gas-pressure was light. In other

words, the sabot was *strong* enough, but not *stiff* enough, to secure a proper "bite" into the rifling.

We have seen how the lower lip, P, of the sabot is pressed upon the base of the projectile by the force of discharge. Acting thus effectually as a gas-check, and excluding the gases from the surfaces of contact of the two metals, not only is stripping prevented, but likewise the breaking off of pieces of iron from the body of the projectile at the junction of the latter with the sabot; this because of the limited expansion of the upper lip, and the consequent slight crowding of the metal at its shoulder. Moreover, as the sabot is kept firmly in place by the downward pressure upon the lower lip, there is no tendency of the sabot to rise above the surface of the shot at *a*, carrying pieces of iron with it. Again, any pressure which obtains between the base of the projectile and the sabot is normal to the bevelled line, *a c;* and the angle at *a* being obtuse, and therefore strong, cannot, it is thought, yield, even if of most inferior metal, under high pressure; indeed, before it could do so, the sabot would undoubtedly "ride up" on the inclined surface, *a c.*

A wide margin obtains for all errors of manufacture, as it is found that very considerable variations may exist in the thickness of the upper lip without affecting the satisfactory action of the projectile. It is only when it is a question of extreme accuracy that the *best* relation between the weight of projectile and thickness of sabot need be considered; which relation, once established, need never be departed from. The principle of the double action of simultaneously taking the rifling and gripping the shot is such that sabots exceedingly light and delicate prove ample for rotating the heaviest projectiles. The inherent strength of an excellent material may be thus developed to its fullest extent, or we may obtain the widest possible margin of safety. I have designedly fired these projectiles when the sabots were full of flaws, with results as faultless as though they had been perfect. Projectiles on which the sabots were loosened, when fired from the gun came out tight and secure. It would seem impossible for any of these projectiles which had passed the most cursory inspection to fail in the slightest particular, from any cause of the sabot, at least.

Admitting that all other objections to the expansive system have been overcome, the question may be asked, How is balloting to be avoided in a projectile centred only at its base? I maintain that if balloting cannot be prevented *absolutely* in this system, its damaging and dangerous tendencies may at least be altogether avoided; and, further, that if balloting be so far corrected that it cannot even cause any irregularity in the flight of a projectile, it is safe to assume that it cannot obtain in sufficient violence to prove hurtful to the gun.

I have discussed, having reference to Fig. I., Plate II., the case of balloting in a soft-sabot projectile where the gases of discharge are entirely shut off by the expansion of the soft metal base; where, as it were, there is no safety-valve through windage, but, *au contraire*, where the higher the powder-pressure, the more hermetical is the sealing of windage.

This closing of windage does not, however, occur in the double-lipped, hard-sabot projectile under discussion, where the depth to which the sabot is expanded into the grooves depends, for the same charge and weight of projectile, upon the width and depth of the grooves, and upon the thickness or stiffness of the upper lip, which may be stiffened either by increasing its thickness or by diminishing its length—*i.e.*, the *depth* of the annular channel, E. In practice, these projectiles have been fired only from the 3-inch guns having seven grooves one-tenth of an inch in depth and an equal number of lands of equal width; from an 8-inch gun having nine grooves .075 inch deep and 1.50 inch wide; and from a 10-inch gun having fifteen grooves .09 inch deep and 1 inch wide. In all these guns, especially in the 8-inch, the upper lip has been expanded into the grooves more completely than I desire, yet the practice has been most excellent, indicating the good effect of even the smallest escape of gas.

Fig. II., Plate II., shows the manner in which the upper lip of the sabot is expanded into the grooves at a position near the muzzle of the gun. The bearing edge, K, having become deepened by attrition in the passage of the projectile through the bore, it is clear that at the seat of the projectile, and during the early acceleration of its velocity, the unoccupied angular portions of the grooves were larger than at the muzzle, although at best such difference must be trifling, since, owing to a slight slip at I, caused by attrition of the opposite side, the unoccupied space at *i* must be increasing in nearly the same ratio as K closes.

Referring again to Plate I., Fig. III., instead of supposing the escape of gas through windage to be effectually shut off, let us suppose that the double-lipped ring is employed, and that under a pressure of 50,000 pounds per square inch the upper lip so nearly fills the grooves that nineteen-twentieths of the entire windage is closed. There will, nevertheless, escape through the unfilled angular portions of the grooves an amount of the forces of combustion which, in the aggregate, distributed about the exterior surface of the projectile, will have a material tendency to buoy and support it (the base being already centred) throughout its passage in the bore. Especially since this supporting medium is passing over the projectile with a velocity vastly greater than that of the projectile itself, and although the pressure per square inch of the escaping gas upon the surface of the projectile be not definitely known, yet it must exceed many

times the weight of the projectile itself per square inch of its surface in front of the sabot. Suppose a bar of iron to be suspended freely from one end, and let down vertically into a swift-running current of water until it is wholly submerged; the pressure of the rapid stream tends strongly to deflect the bar from a vertical position, and it assumes a certain angle with the surface of the stream. Now, substitute for this bar of iron, one of no greater specific gravity than the water itself, and it will quickly assume a position parallel to the surface of the stream. I am satisfied that this is but a feeble illustration of the effect of the rush of powder-gases over the surface of a projectile when centred at its base. In the particular case under consideration nineteen-twentieths of the windage is closed, and through the partly obstructed grooves the gas of discharge is forced under a pressure of 50,000 pounds per square inch, and is immediately afterwards dispersed through a space twenty times larger in cross-section than that through which it escaped from behind the projectile. The pressure about the projectile is, therefore, correspondingly reduced; and it is still further reduced, probably, from various causes; but I much question if, in the case in point, the average pressure upon the surface of the shot in front of the sabot would not approximate 2,000 pounds per square inch.* As it is a remarkably heavy projectile which will weigh one pound per square inch of its cylindrical surface, is it not reasonable to suppose that a medium so dense, rushing over a projectile centred in the rear (and which projectile bears a more feeble relation to the great force surrounding it than does a feather to a gale of wind), must tend powerfully to check balloting? And is it likely that balloting, under such circumstances, if it occur at all, must lose all its dangerous and vicious tendencies? It is a different story, indeed, when windage is hermetically sealed, when there is no safety-valve for the rapidly-developed gases: for then balloting or wedging begins; the pressure increases; it may be that the limit of endurance of the powder grains or prisms is reached; the powder disintegrates and consumes with a flash; the projectile, for every increase of pressure behind it, opposes fresh resistance to its own egress, and we may count it fortunate that it escapes from the bore uninjured.

The breech-loading projectile (lead-coated), it is true, shuts off windage, but it is *centred* throughout its length, or at least *supported* through its cylindrical portion, and cannot therefore ballot, nor is it likely to wedge or jam in the manner here alluded to.

The value of a limited windage as a promoter of accuracy may, I think, be

* This pressure upon the cylindrical part of the projectile could doubtless be readily determined by screwing into the side of the projectile a pressure-gauge with a delicate knife.

readily shown; indeed, its advantage in this respect is quite marked. Innumerable instances are afforded where projectiles of the expansive class, with *soft sabots*, have given a large percentage of fluttering or irregular flights; and yet, after examination of many recovered shot, a fair impression of the rifling indicated that the full value of the pitch had been taken. This apparent anomaly is to be explained on no other hypothesis than that balloting occurred, as shown in Fig. I., Plate II., not with sufficient violence to injure materially either gun or projectile; but the latter, cleared of the restraint of the bore at the last rebound, had no recourse but to take up the double motion of rotation about a point as well as its axis, yielding flights variously characterized as "irregular," "wild," "wobbling," "puffy," or "tumbling"; although "tumbling"—*i.e.*, the turning of the shot end over end in its flight—is not apt to occur when the "rifle motion" is imparted, unless balloting be excessively violent.

Having advanced the assertion that a very limited windage over an expansive projectile, centred in the rear, will so far reduce the violence of balloting as to render it harmless to gun and projectile, I have next to assert, with equal confidence, that a *proper* windage (still small, however) will not only accomplish this desideratum, but will so far obviate balloting as to ensure to the projectile *infallible* smoothness and steadiness of flight—granted, of course, that the sabot performs its function of imparting to the projectile the full value of a proper pitch. The use of the projectiles under discussion *ensures* this windage, and to this fact I largely attribute their infallible accuracy and smoothness of flight.

I have already alluded to the frequent occurrence of irregular flights of expansive projectiles which closed all windage, when there was every reason to believe the rifling to have been perfectly taken by the sabot; and in further support of the position I have taken on this question, I may mention a fact on official record, that in the course of upwards of one hundred rounds with the proposed projectile such a thing as a fluttering or in the slightest degree unsteady flight has never been discovered. A further proof of the correctness of this theory may be afforded in an interesting experiment made by Colonel Baylor to test the strength of the new sabot.

It will be observed that the upper lip of the split or grooved ring may be made so thin as almost entirely to check windage, and yet, as has been explained, possess sufficient strength to rotate the heaviest shot. It may also be made so extremely thin as to close windage while the projectile is getting under way, but, through sheer lack of stiffness, ride over the lands toward the muzzle. This property of the projectile has quite inadvertently furnished an additional test of the effect of windage on the accuracy of expansive projectiles. After two

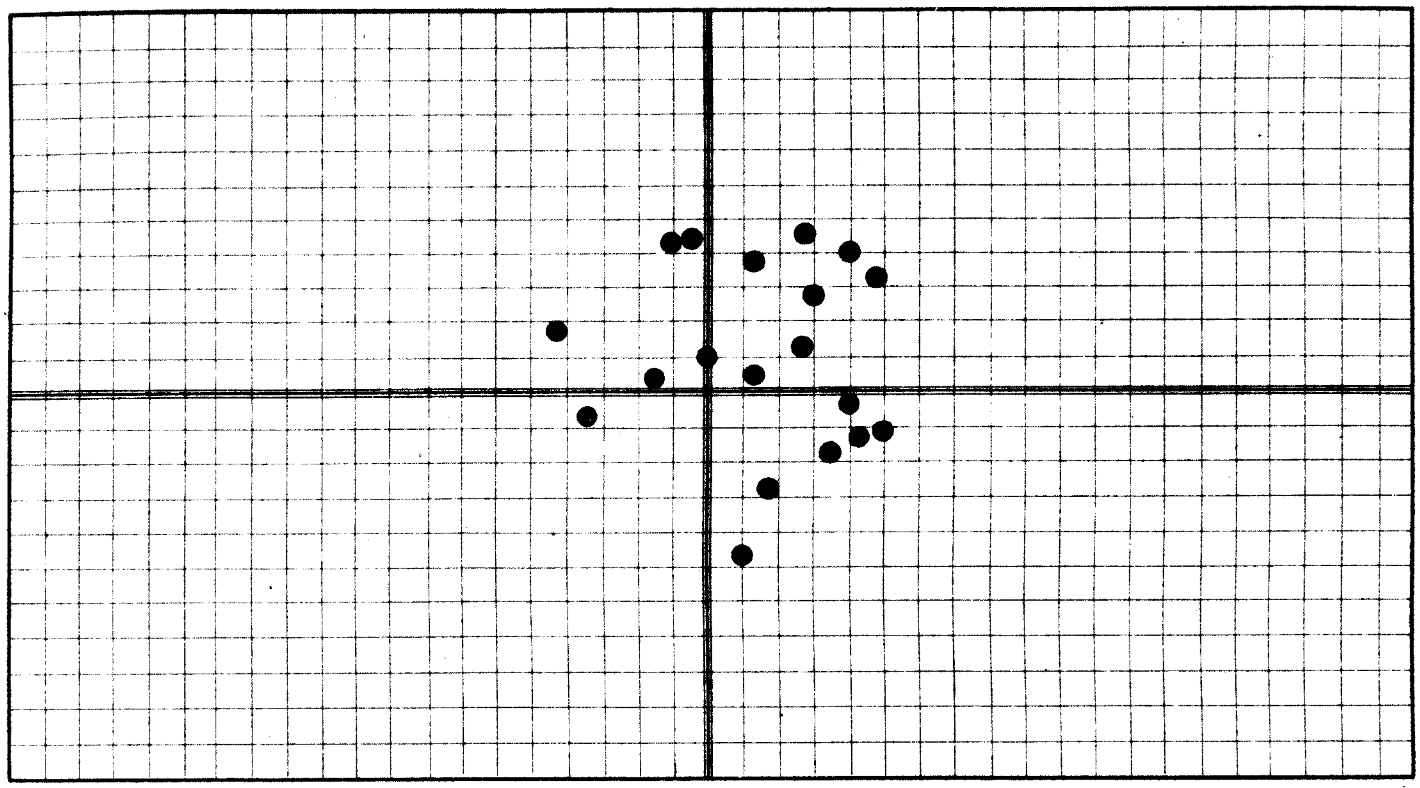
series of experiments with projectiles of $10\frac{1}{2}$, $11\frac{1}{2}$, and $12\frac{1}{2}$ pounds, in each of which cases superior accuracy was shown, about twenty of the same projectiles were made $12\frac{1}{2}$ pounds each in weight, and fitted with very thin and delicate sabots. These shot were fired from the same 3-inch gun previously used. The sabots proved abundantly strong, rotated the projectiles perfectly, as could be judged by those recovered, and every flight was smooth in *sound*. But while the perfect action of the sabots, together with the fact that *all* windage was probably not closed, prevented any unsteadiness of flight, still the contrast in accuracy presented to the previous firings, where the sabots were not allowed to set up so freely into the grooves, indicated clearly that the projectile could not have been absolutely steady in the bore of the gun. The great weight of these projectiles—of the same size and shape as those previously fired—combined with the lightness of the sabot, would, of course, cause the latter to be well *set up* into the grooves. *All* the gas, however, was not shut off; and although balloting did not obtain to an extent sufficient to cause a "fluttering" flight, yet it caused a deviation from the true line of departure of the projectile only reconcilable with the probability of too much weight of metal to support and too light an envelope of gas to support it. And in general it is safe to assume that whenever the flight of a projectile is observed to be smooth, steady, and accurate, it is the best *primâ facie* evidence in the world that balloting has not obtained; and, on the other hand, the full value of the twist may be communicated to the projectile, and yet the latter give a very irregular flight; and when this is the case, and the rotating device—whether a sabot, jacket, or studs—is uninjured, it is good evidence that balloting has occurred, and to an extent or violence very clearly indicated by the flight, according as it is irregular, very irregular, puffy, or wobbling. Bear in mind that I speak only of cases where the *rotation* of the projectile is *assured*; for, failing this, there might be no balloting, yet the projectile would, of course, soon after leaving the bore, "*tumble*" from its natural tendency to rotate about its shorter axis.

Admitting the correctness of these views in the case of expansive projectiles, it follows, 1, that the lighter the shot for a given superficial area, the more readily is it centred by the supporting gases; and, 2, that for the same weight and exterior form of projectile, that which has the centre of gravity nearest the sabot will have the least tendency to ballot (under a proper gas-escape), and, therefore, possibly the smoothest passage through the bore. As nearly all projectiles have the centre of gravity in rear of the centre of figure, this is a point always in favor of our expansive system. Once clear of the bore, it may be an advantage to have the centre of gravity in *front* of the centre of figure; but as

Plate IV.

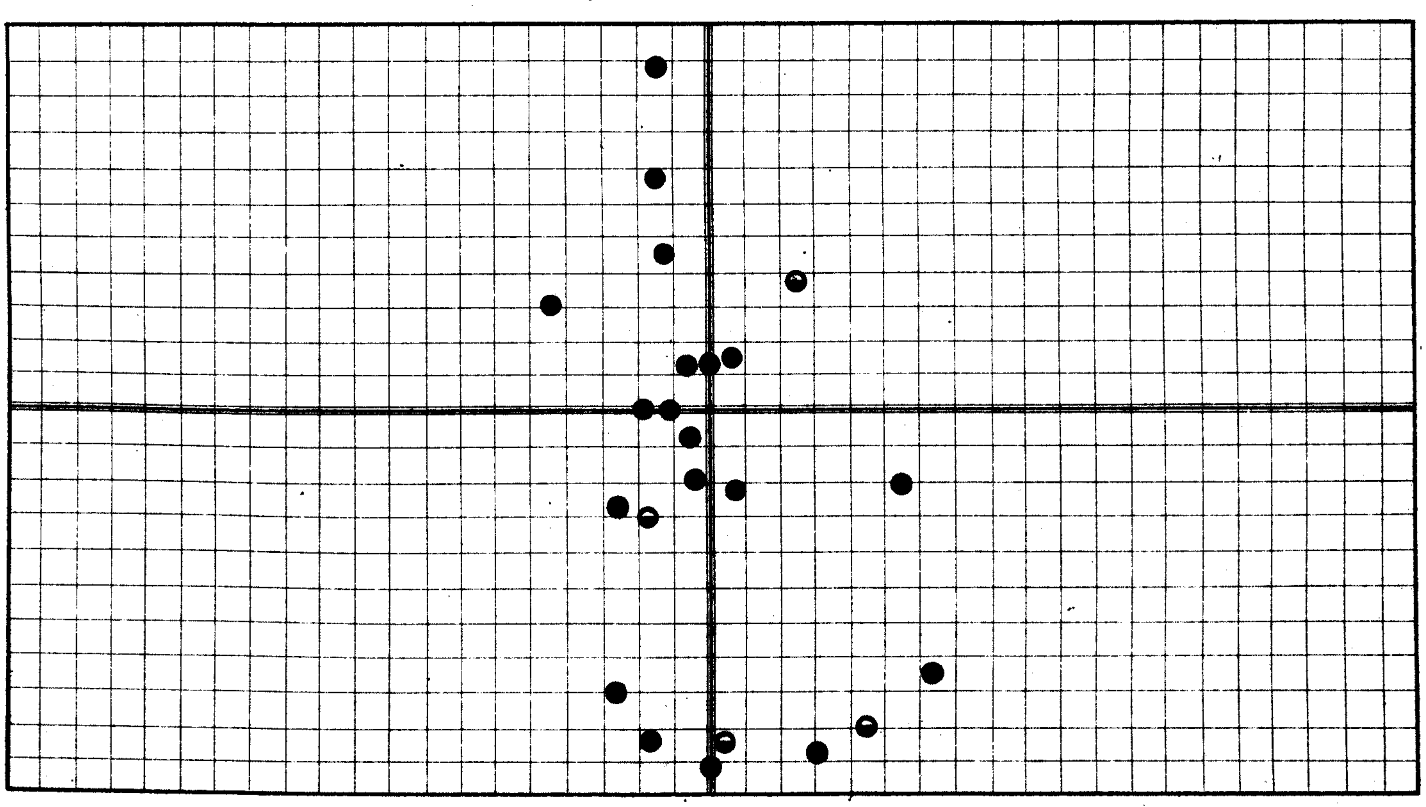
3 Inch Rifle.

Target 820 Yards.



FORT MONROE APR. 1871.

Target 1500 Yards.



FORT MONROE JULY 1871.

D. Van Nostrand, Publisher. New York.

the relative positions of these two points are subject to very limited changes, any advantage one way or the other is not worth a moment's consideration.

In this discussion of the advantages of a moderate windage as applied especially to our expansive system, I have not lost sight of the general advantages of windage, as so long ago recognized in France, England, and other countries. These advantages, briefly set forth, and of more or less value, are:

1. Increased accuracy.*
2. Much less fouling of the gun.
3. Reduction of the pressure.
4. Regulation of pressure.
5. Less violent recoil.
6. The surer ignition and more simple character of time-fuse.

Something over one hundred of the 3-inch projectiles (similar in form to that on Plate IV.) have been fired, a few for range, some into the butt, and some at targets. Their record is very perfect, and shows:

1. Very superior accuracy.
2. Great steadiness and smoothness of flight.
3. Not a single case of stripping.
4. Not a single failure to take the grooves.

How long we might be able to continue firing these projectiles without a failure in any particular to record, it is impossible to say; but, bearing in mind this record of a first attempt, the great strength of the shot, and the wide margin thereby afforded for all flaws, defects, or errors of manufacture, it is thought that the number of failures in any one of the above particulars would be but a small percentage at least. We consider it but indifferent small-arm ammunition which yields as high as one per cent. of failures; and as the failure of a field-projectile is of far greater moment than of a small-arm cartridge, no effort should be spared to render our projectiles as nearly infallible as possible. If a field-projectile is inaccurate, falling short or beyond, to right or left, of the object

* *Edinburgh Review*, April, 1864: "The result of the more recent experience of the French artillerists proves that the suppression of windage diminishes the accuracy of fire. . . . When the projectile is driven forwards to the muzzle of the piece by the expansion of gas generated by explosion, the point of time at which it leaves the gun decides its direction, and the slightest variation of pressure from within or without at that instant causes deviation in its subsequent flight. The absence of windage is now thought by the French to increase the probability of such accidental variation of pressure; but when a portion of the gas generated by the explosion is allowed to escape by windage, as this gas travels four or five times faster than the projectile, it serves, as it were, to prepare the atmosphere for the ball, and to launch it on the straight line to its trajectory."—"Ordnance and Armor," Holley, page 541.

aimed at, it disturbs the aim of one or two succeeding shots; while, if it strip, a casualty amongst our own troops from such a cause is more demoralizing than a hundred deaths from the missiles of the enemy.

It is not my present purpose to discuss the relative merits of the breech and muzzle loading systems so much as to reveal their present defects and in each to propose a remedy; yet it is fair to say that a chief argument in favor of the breech-loading system has always been its superior accuracy, and I venture the opinion that if equal accuracy can be assured with muzzle-loaders, a large majority of artillery officers will pronounce in favor of the simpler system of muzzle-loading field-pieces, and especially in the expansive system, where the grooves have not to be *fed* by studs on the projectile, but where the latter are freely inserted and quickly driven home.

Captain Nicaise, of the Belgian service, has written a memoir intended to prove the superior accuracy of the Belgian (Krupp) breech-loading field-pieces over every other system of which he has knowledge. The targets given on Plate IV., which represent practice with our new expansive shot, will be found to compare favorably with the best practice as recorded by Captain Nicaise. In making this comparison it should be borne in mind: *

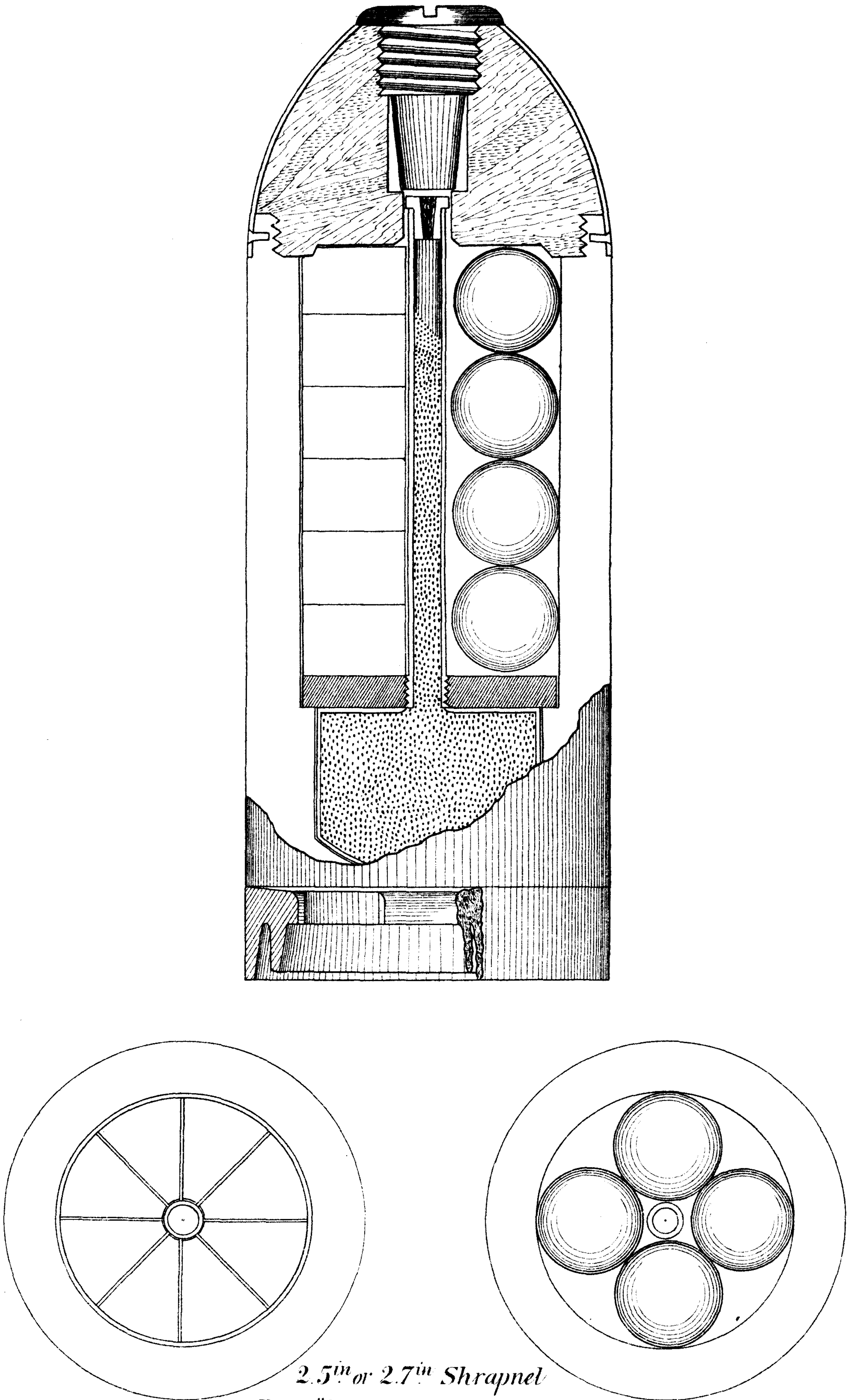
First, the target records published by Captain Nicaise are selected from a large number of results; and as he was probably aware that his readers would credit him with selecting the *best* records for publication, he has probably governed himself accordingly. On the other hand, the targets here given are the *only* ones available, our experiments being thus limited.

Second, the Belgian experiments were so extensive that an exact graduation of the sights was doubtless effected by a suitable number of shot; whereas, in our experiments, *three* shots were allowed with which to "feel" for each target. All the shots fired will be found plotted upon the targets, except four.

Third, the Belgian projectile weighed but little over nine pounds, was fired from a gun 3.15 inches calibre, and with charges of $1\frac{1}{4}$ pound of powder. In our experiments, it being a principal object to test the strength and other qualities of the projectiles independently of accuracy, one-half of the shells fired at 1,500 yards were packed with lead balls, so that their weight exceeded eleven pounds each. This rendered the trajectory an exceedingly curved one, as the charge remained unchanged and less than one-eleventh the weight of the projectile, whereas good practice required it to be at least one-eighth.

Fourth, the powder employed was irregular, being about ten years old, and obtained from broken-up ammunition.

* Letter to *Army and Navy Journal*.



2.5in. or 2.7in. Shrapnel
For "Mountain" service.

D. van Nostrand, Publisher. New York.

Taking into consideration, then, these facts, I think there is no question that, good as our practice must be pronounced, it can be excelled without difficulty under circumstances as favorable as those under which the Belgian practice probably occurred.

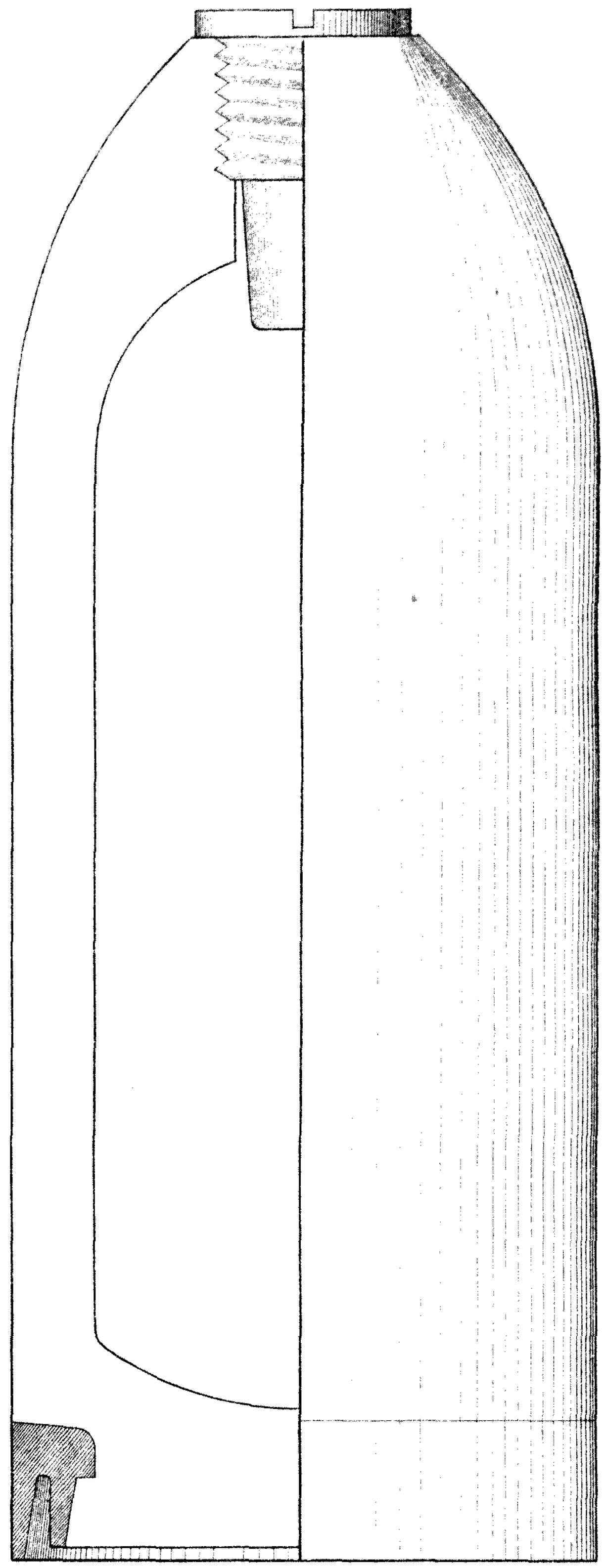
The target at 820 yards, which I here take the liberty to reproduce, is from the official records of experimental firing with the 3-inch gun at Fortress Monroe on April 20, 1871. The firing at 1,500 yards occurred July 18, 1871. This last target would be better; but observing that the shot were clustering too low, the gun was raised upon the target, with the effect observed, viz., *two* clusters separated by a considerable interval. Make allowance for this, and the breech-loader is beaten even at a disadvantage of nearly 200 yards in the distance fired over. I see no reason, therefore, to doubt that the best practice heretofore obtained with breech-loaders can be equalled without difficulty in this country with our muzzle-loading guns. As to the European muzzle-loading systems (stud-projectiles), from the best information available, including the interesting data supplied by Captain Nicaise, it is believed that their practice is quite inferior.

By reference to Prof. Owen's "Modern Artillery," Captain Nicaise's "Belgian Field Artillery," and to Colonel Baylor's official reports of experiments with the three-inch rifle, the following data are obtained:

TABLE II.

Comparative Velocity and Accuracy of Breech and Muzzle Loading Field-Projectiles.

Gun.	Calibre.	Weight of Charge.	Weight of Shot.	Initial Velocity.	Deviation.			Distance of Targets.
					Vertical.	Horizontal.	M	
	Inches.	Pounds.	Pounds.	Feet.	Feet.	Feet.	Feet.	Yards.
English B. L.	3	1⅛	8¾	1,057				
" M. L.	3	1½	9¼	1,176				
French M. L.	3		8¾	1,066	6.56	4.59	8.05	1,312
" "	3		8¾	1,066	10.17	6.23	11.93	1,640
Belgian B. L.	3.09	1¼	9¼	1,220	2.69	3.18	4.16	1,312
" "	3.09	1¼	9¼	1,220	1.61	1.80	2.41	875
U. S. M. L.	3	1	11⅛	1,052	4.12	1.41	4.35	1,500
" "		1	9⅛	1,200	2.00	2.30	3.10	820
" "		1¼	9¼	1,300				
" "		1½	9¼	1,365				
" "		1¾	9¼	1,400				



Proposed 2.7^in Shell.
For "Mountain" service.

D. Van Nostrand, Publisher, New York.

surpassed in accuracy and unequalled in many other qualities which go to make up a *perfect* projectile.

The Ordnance Department having adopted the calibre of 3.5 inches for a field-gun, it would be wise, in my judgment, to abandon our present 3-inch rifle, and to substitute a lighter gun of smaller calibre, say 2.5 inches or 2.7 inches. Plate V. illustrates the case-shot for a 2.5-inch gun and two plans of filling. The forty-eight segments of lead would make the heavier projectile, and each fragment possesses weight sufficient to do execution with moderate velocity. The sixteen lead balls, each weighing $1\frac{1}{3}$ ounces, shown on the right, would prove effective at longer ranges and with lower velocities. A practical test would be necessary to determine the relative merits of the two plans. On Plate VI. is shown a 2.7-inch shell.*

It is chiefly, however, in large calibres that the advantages of the proposed projectile will probably be manifested, and especially so in connection with certain slight modifications of our present forms of rifling already referred to, and which will now be briefly described.

THE RIFLING.

In discussing the action of the double-lipped ring in the bore of a gun, I have heretofore considered only the case where the gases of discharge find passage over the projectile through the unoccupied angular portions of grooves similar to those in our present rifled guns. I consider it highly desirable, however, to slightly increase this windage, more especially in large guns, and thus place the satisfactory action of the projectile and, as far as may be, the safety or good endurance of the gun beyond a peradventure.

If we conceive a system of rifling with wide grooves and very narrow lands, it is just such a system, of course, which best assures filling of the grooves by any expansive device under the explosive force of the powder. Now, conceive

* A field-gun of this calibre would undoubtedly prove a most efficient arm—a 25-inch has already been adopted abroad. It would occupy the same relative position to the 3.5 rifle (16-pounder) that our mountain howitzer does to the 6-pounder and 12-pounder smooth-bores, and would prove far more formidable, except with canister, than either of the latter guns, and scarcely less efficient than our present 3-inch gun; it would, in fact, give better results than the 3-inch did during the late war, served as it was with poor projectiles. Weighing scarcely half so much as our lightest field-piece, it could be placed in positions inaccessible to heavier guns. Lightness, mobility, simplicity of equipment, cheapness, and the small force necessary to serve efficiently a battery of such guns, are advantages not to be gainsaid, especially if the gun should be proved to possess good range and accuracy. To enumerate specifically all the important uses to which such a battery would be put during an ordinary campaign is unnecessary, as this ground has been well covered by others. I think it probable that efficient guns of this and even larger calibre could be made from old material (bronze guns) now on hand.

these grooves to be gradually narrowed, it is clear that it will be more and more difficult for the sabot to fill them, and they may be made so narrow as absolutely to prevent the sabot taking sufficient "bite" to keep the grooves during the passage of the projectile through the bore of the gun. Between these two extremes I have fixed what I deem a judicious width of grooves and lands—grooves which cannot be completely filled by the expansion of the upper lip of the sabot, and whose numbers are sufficient to assure a reasonable gas-escape through their unfilled portions; and lands somewhat wider than the grooves—a provision which, besides conducing to the endurance of the bore, renders the firing of spherical projectiles, grape-shot, and canister practicable, with but little liability of the gun to sustain damage thereby, or to diminish the accuracy and effect of such projectiles.

This plan of rifling is illustrated on Plate VII., which gives, in connection with the following table, the proposed rifling for every gun from 2½ inches up to 15 inches calibre.

TABLE III.

Proposed System of Rifling for Muzzle-loading Guns.

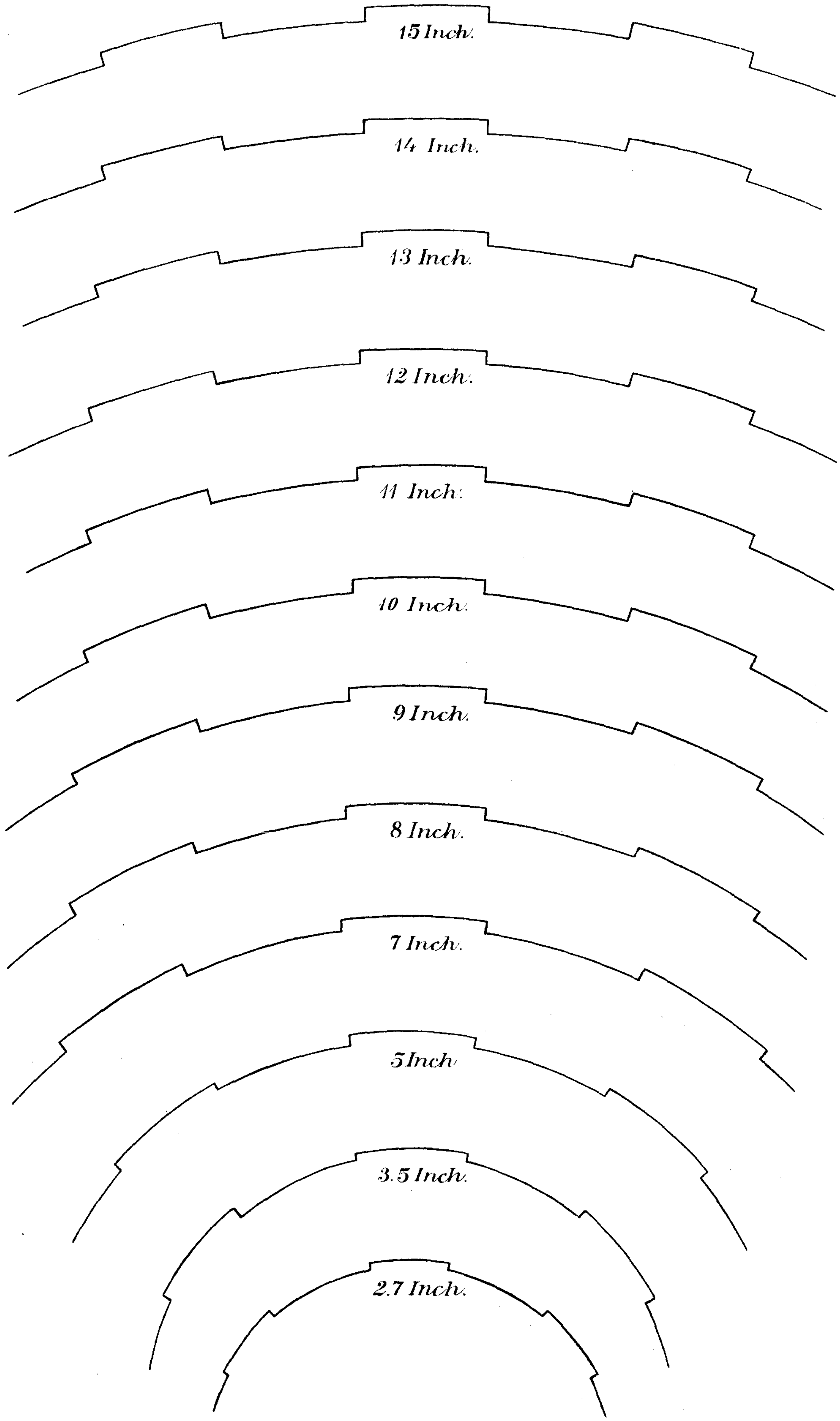
Calibre of Gun.	Number of Grooves.	Depth of Grooves.	Width of Grooves.	Pitch.		Ultimate Pitch.
				Commencing.	Ending.	
Inches.		Inches.	Inches.	Calibres.	Calibres.	Feet.
2.5	7	0.050	0.52	68	34	7.08
2.7	7	0.055	0.56	70	35	7.87
3.0	7	0.060	0.64	72	36	9.00
3.5	7	0.065	0.74	76	38	11.08
4.5	9	0.070	0.74	86	43	16.12
5.0	9	0.070	0.83	90	45	18.75
6.0	11	0.075	0.81	98	49	24.50
7.0	11	0.075	0.95	106	53	30.91
8.0	13	0.080	0.92	112	56	37.33
9.0	15	0.080	0.90	118	59	44.25
10.0	17	0.085	0.87	124	62	51.66
11.0	19	0.085	0.85	130	65	59.58
12.0	21	0.090	0.85	136	68	68.00
13.0	23	0.090	0.83	144	72	78.00
14.0	25	0.095	0.82	150	75	87.50
15.0	27	0.095	0.81	156	78	97.50

☞ The bottom corners of the grooves should be rounded to a radius of from 0.01 to 0.02 of an inch.

Plate VII.

Rifling for Expansive System.

Table III.



D. Van Nostrand, Publisher. New York.

While it is thought that the above system is admirably adapted to the new projectile, yet, should it be thought advisable to secure a still more liberal gas-escape, with a view to the employment of projectiles of unusual weight or powder of especial violence, this end may be accomplished in the manner shown on Plate II., where the bottom of each groove is again grooved through its centre, as in A, Fig. III., or where the secondary groove is placed on the non-bearing side of the principal groove, as in B, Fig. III.—a position more favorable for a liberal gas-escape. Or, if it be thought objectionable to sub-groove the gun in this manner (although the ultimate depth would be less than that of the English groove), additional gas-escape may be provided by the old plan of grooving the projectile for the ignition of time-fuses, or by providing channels communicating from the base to the cylindrical portion of the projectile.

I have not lost sight of the objection urged against windage that the bore of the gun is "gutted" by the cutting action of the escaping gas. In the first place, this is an objection common to almost all systems (the soft-sabot expansive, perhaps, excepted). In the second place, the gas-escape here recommended is much less than that of the English, and less even than that of the breech-loading systems, where the gas rushes over the projectile as it lies in the chamber before closing windage by entering the bore; and, finally, experience has proved that, with either cast or wrought iron guns, hundreds of rounds may be fired, allowing a moderate gas-escape, without any injury to the bore whatever. Indeed, this "scoring" action of the gases is but faintly manifested in rifled guns of cast iron, even after a thousand rounds with expansive projectiles.

The pitch of the rifling given in the foregoing table is almost identical with that of the few rifled guns now in our service (excepting, of course, the Parrott guns), and is only altered to an extent which makes it consistent as applied to different calibres. It is clear that the pitch of the rifling need be no more than will suffice to keep the projectile invariably true throughout its longest flight; and that if, after having ascertained as exactly as possible what such a twist would be, we increase it in a very moderate degree, we have all the rapidity desirable or necessary.

Actual experiment at Fort Monroe having shown that a twist of one in one hundred in a 7-inch gun was sufficient to keep a projectile of 100 pounds true through a range of three miles, it is certainly safe to assume that a pitch of one in eighty would suffice for the longest range from such a gun. As the actual work, however, of giving to an ordinary projectile the rotation due to such a pitch would be but a small fraction of the actual work expended on the projectile, we can (although the resistance increases in a very rapid ratio with the angle of

rifling) afford to considerably increase the rapidity of pitch for calibres of seven inches and less. As we go up in calibres, however, the increase in the radii of gyration of the projectiles enables them better to sustain rotation, so that, their angular velocities being less rapidly diminished by air-friction, less is required at the start. The Krupp 12-inch rifling has one turn in seventy-one feet, yet the large, roughened surface of the lead-coated projectile, after it leaves the bore, must cause this projectile to lose rotation much more rapidly than do the smoother projectiles of the expansive class.

The rifling in the foregoing table is given with confidence that the pitch is amply sufficient even with moderate velocities and the smallest charges—as, for example, where it may be wished to throw a siege-projectile but a moderate distance with a curved trajectory; and I am equally confident that a variation of twenty per cent. either way from such a pitch would still yield excellent results with our expansive system.

It remains simply to be considered whether the pitch should be uniform or increasing. The advocates of the increasing pitch contend that the shot should be under as little restraint as possible in getting under way, and that rotation should be communicated and increased while the shot is acquiring its velocity. On the other hand, the advocates of the uniform pitch claim that not only is such an end accomplished by the natural increments in the velocity of the projectile, but that when the projectile is just getting under way is the time when it can most profitably be given rotation. Without going over the somewhat trite arguments of either side, it is just to say that there are in the views of each points of value. While, however, both parties cannot be altogether right, both may very readily be wrong, and I submit the propriety of testing (and it could be safely adopted outright) a *compromise pitch*, by which is meant simply one which commences at the seat of the charge, with one-half of its ultimate value at the muzzle; as, for example, a uniformly accelerating groove, commencing with one turn in a hundred and twenty, and ending with one in sixty.

The English 12-inch 25-ton gun is rifled on this plan, although the pitch usually employed in that service commences at 0. The English system of rifling and projectiles is, however, so bad that it is doubtful if the compromise pitch possesses much advantage over the others.

The gradual but steady improvement in gunpowder renders of less and less weight the argument for a full increasing pitch—that is, one where the tangent of the groove at the seat of the charge is parallel to the axis of the bore; and, on the other hand, the uniform twist can only be desirable when the acme of perfection in gunpowder has been attained, and, until such a desideratum is reached,

I am persuaded that the proposed pitch is absolutely the best available, and will always be efficient, no matter how marked the future improvements in gunpowder.

The following table will exhibit some of the considerations which lead me to this conclusion. There is here taken the case of an 8-inch gun, rifled on three different plans, having in each case an ultimate pitch of one turn in sixty calibres. The assumed velocities are approximately correct, and are based upon the results of recent experiments with English "Pebble" powder, in comparison with the old "R.L.G.," "Service Pellet" and "Russian Prismatic" powders.

TABLE IV.

Showing the velocity of a projectile at different points of the bore of an 8-inch rifle, and the circumstances attending rotation in three different characters of "Pitch."

Distance Moved by Shot.	Velocity of Shot.	Uniform Pitch			Full increasing Pitch.			Proposed Pitch.		
		Angle of Tan, with Axis of bore.	Revolutions of Shot per Sec.	Gain Every Six Inches.	Angle of Tan, with Axis of bore.	Revolutions of Shot per Sec.	Gain Every Six Inches.	Angle of Tan, with Axis of bore.	Revolutions of Shot per Sec.	Gain Every Six Inches.
Inches.	Feet.	Degrees.			Degrees.			Degrees.		
0	0	3	0.000		0.0000	0.000		1.5000	0.000	
1	40	3	1.000		0.0313	0.010		1.5156	0.505	
2	125	3	3.125		0.0627	0.065		1.5312	1.595	
3	220	3	5.500		0.0941	0.172		1.5468	2.836	
4	300	3	7.500		0.1254	0.312		1.5625	3.906	
5	375	3	9.375		0.1568	0.488		1.5781	4.931	
6	445	3	11.125	11.125	0.1881	0.695	0.695	1.5937	5.910	5.910
7	495	3	12.375		0.2195	0.902		1.6094	6.639	
8	540	3	13.500		0.2408	1.125		1.6250	7.312	
9	590	3	14.750		0.2822	1.352		1.6406	8.066	
10	630	3	15.750		0.3135	1.641		1.6562	8.695	
11	675	3	16.875		0.3449	1.932		1.6719	9.404	
12	720	3	18.000	6.875	0.3762	2.250	1.555	1.6875	10.125	4.215
18	865	3	21.625	3.625	0.5644	4.055	1.805	1.7812	12.839	2.714
24	975	3	24.375	2.750	0.7525	6.094	2.039	1.8750	15.286	2.447
30	1,055	3	26.375	2.000	0.9406	8.242	2.148	1.9693	17.308	2.022
36	1,130	3	28.250	1.975	1.1287	10.594	2.352	2.0625	19.322	2.014
42	1,190	3	29.750	1.500	1.3169	13.016	2.422	2.1562	21.382	2.060
48	1,240	3	31.000	1.250	1.5050	15.500	2.484	2.2500	23.250	1.968
54	1,275	3	31.875	0.875	1.6931	17.929	2.429	2.3437	24.902	1.652
60	1,305	3	32.625	0.745	1.8812	20.391	2.462	2.4375	26.508	1.606
66	1,330	3	33.250	0.625	2.0694	22.859	2.468	2.5312	28.055	1.547
72	1,345	3	33.625	0.375	2.2575	25.219	2.360	2.6250	29.422	1.367
78	1,360	3	34.000	0.375	2.4456	27.625	2.406	2.7187	30.812	1.390
84	1,370	3	34.250	0.250	2.6337	29.969	2.349	2.8125	32.109	1.297
90	1,375	3	34.375	0.125	2.8846	32.227	2.258	2.9062	33.301	1.192
96	1,380	3	34.500	0.125	3.0000	34.500	2.273	3.0000	34.500	1.199

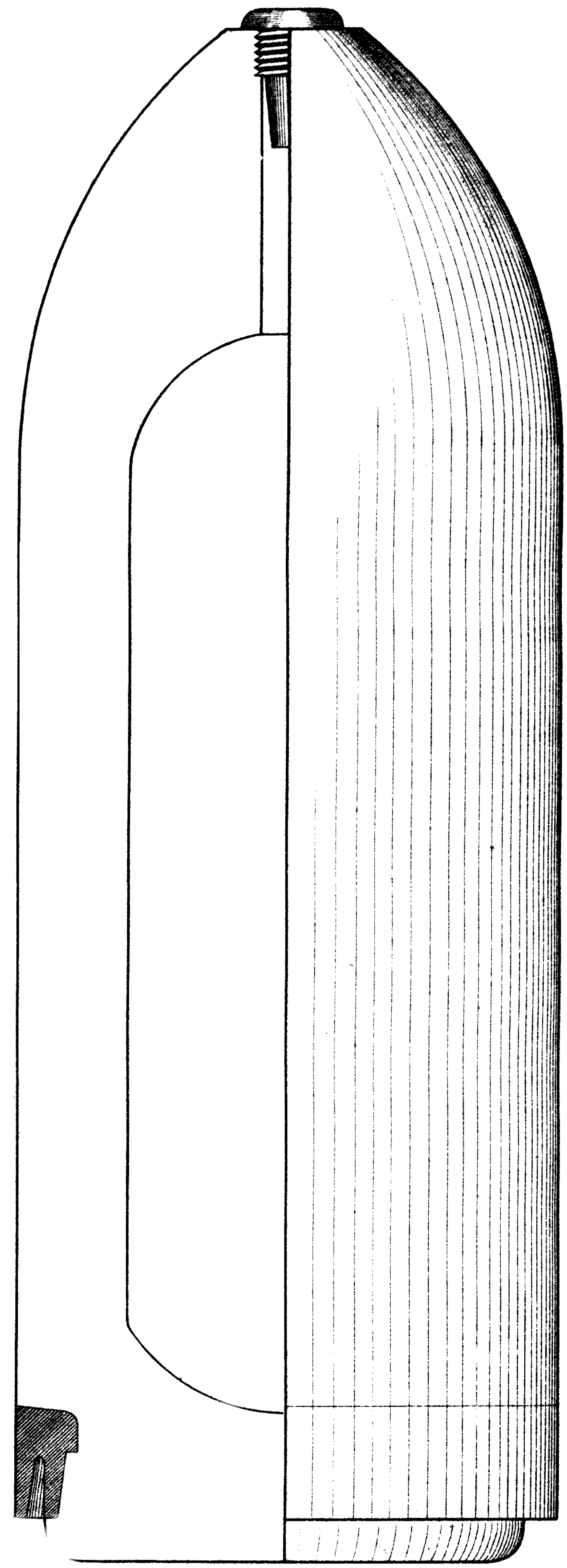
The English "Pebble" powder is very nearly the equivalent of our own "Hexagonal," and the table may be considered as exhibiting quite accurately the action of our 180-pound 8-inch projectile throughout the first eight feet of the bore when fired with a 30-pound charge.

From this table it will be seen that, in the uniform pitch, *nine-tenths* of the work of rotation is done in the first forty-eight inches of the bore; *one-half* of it in the first twelve inches; and *one-third* in the first six inches; while in the full increasing pitch the work of rotation is thrown almost entirely upon the muzzle portion of the bore, the breech end of the rifling doing comparatively nothing. For example, in the uniform pitch, the shot, when but six inches from its starting-point, is rotated at the rate of over *eleven revolutions per second*, while the full increasing pitch does not impart rotation at the rate of a *single revolution per second* in the same distance. Again, in the former rifling over *one-half*, and in the latter but *one-thirtieth*, of the ultimate rotation is imparted to the shot in the first twelve inches of its progress through the bore.

As to the relative effect on velocity of these two plans of rifling, experience has proved that the difference is but slight, the retardation of the projectile in the breech of the gun by the uniform grooves having very nearly the same effect on the ultimate velocity as the checking of the projectile by the full increasing pitch as it approaches the muzzle of the gun, where the action of the gases is but feeble.

Although it is thought that the proposed pitch will possess an advantage over either of the others in respect to velocity, it is for other and more important considerations that the change is recommended. If we reflect upon the marvellously short time (0.0037 second) in which a projectile, in the first six inches of its course, is rotated at the rate of eleven times per second, or, in the case of the full increasing pitch, when we consider that the greater part of rotation is conveyed by the muzzle portion of the rifling in something like the .0035 second, it will, I think, be acknowledged that in both systems the work of rotation is most unevenly and unwisely distributed throughout the bore, and is far from economically so as regards the "wear and tear" on both gun and projectile. Such distribution of the work of rotation must likewise, it is thought, retard velocity, while stripping or other misconduct on the part of the projectile will be more liable to occur in either of these systems than in the one proposed.

Glancing down the last two columns of Table IV., it will be seen how uniformly the work of rotation is developed throughout the bore of the gun in the case of the compromise pitch. At a time when the projectile is getting under way, and has but a low velocity and slight friction, advantage is taken of



Siege Projectile.

D. Van Nostrand, Publisher. New York.

these circumstances to impose upon the rifling *some* of the work of rotation; avoiding, however, the two extremes presented in the other plans, of excessive work on the one hand and very little on the other. The lower half of the rifling accomplishes *two-thirds* of the rotation, instead of *nine-tenths* as in the uniform, or *two-fifths* as in the full increasing pitch.

It would be easy to adopt a pitch which, with a given powder (say that here selected for comparison), would distribute with absolute uniformity the work of rotation along the grooves; and while such a plan would, I think, be preferable to any of those now in use, yet it is thought that this work is distributed to the best advantage by the plan proposed, which shows for the lower portion of the bore slight increments of the work of rotation, and for the upper and weaker portion of the bore, and where the gases become more attenuated, a slightly decreasing rate of acceleration.

It is believed that the compromise pitch here described possesses superior advantages over the other plans, and that its adoption would be attended with increased efficiency and endurance in both guns and projectiles, and that a careful inspection of Table IV. will afford good argument for such a change.

Table V. presents an opportunity of comparing the ultimate pitch of our rifling with that of three of the principal European powers. The Russian, Prussian, and American are seen to compare closely, and although, as has been stated, our projectiles must lose rotation less rapidly than the roughened, lead-coated shot, nevertheless the angle of our pitch is generally the greater. With increased charges of improved powder, and the greater weight and velocity of our new projectiles, I am convinced that our pitch is ample, but am far from persuaded that it is not unnecessarily rapid.

In the English "Treatise on Ammunition," Part II., by Capt. C. O. Brown, R.A. (late Captain Instructor, Royal Laboratory), it will be seen that the length of projectiles in the English service varies from $2\frac{1}{2}$ to 3 calibres, including the ogival head. With this form of projectile it is stated "that it has been ascertained by experiments that a twist of about one turn in thirty-five calibres gives the best results, and that any material deviation from this amount in large guns tends to render the projectiles more or less unsteady in flight."

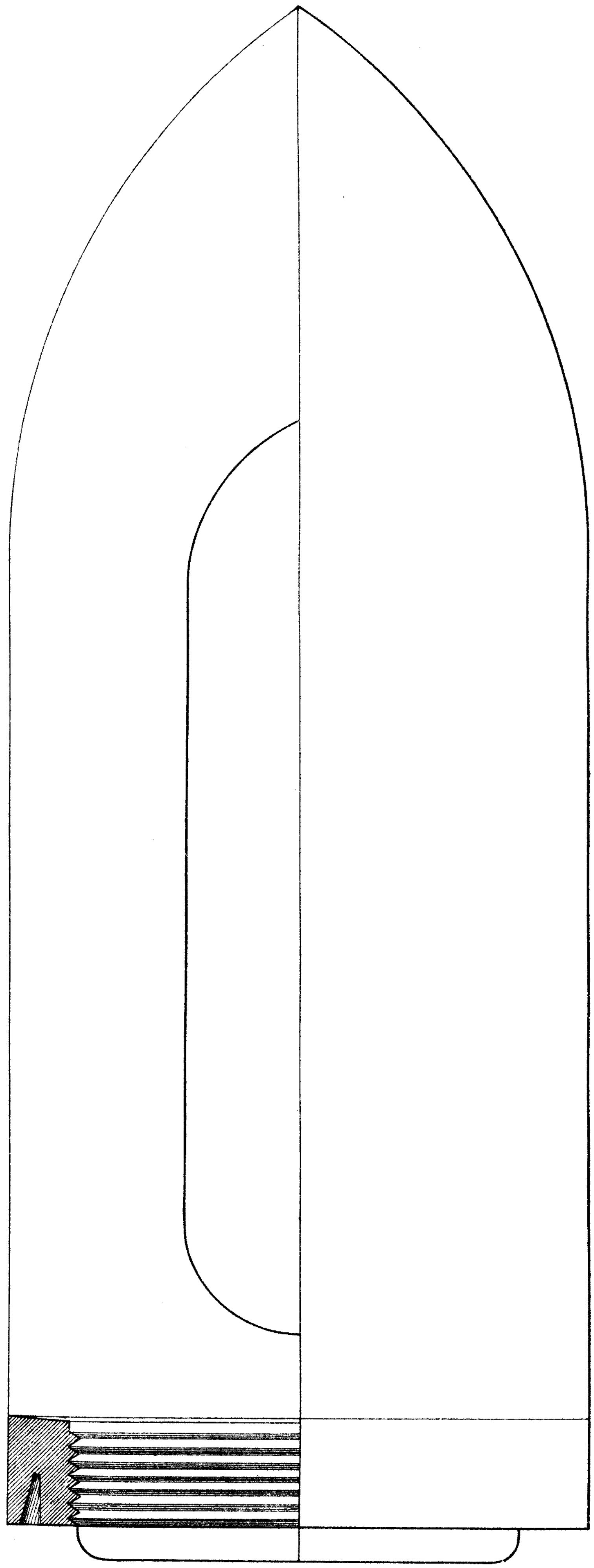
We know how much in error this statement is, except, perhaps, as applied to the English system of rifling; for it must be acknowledged that a pitch of one turn in sixty, or one in seventy, calibres is a very "material deviation" from one in thirty-five calibres, yet such a pitch has proved ample for giving smooth and accurate flights to projectiles of $2\frac{1}{4}$, $2\frac{1}{2}$, and $2\frac{3}{4}$ calibres in length, and will do so invariably when the projectile behaves properly, both in Krupp's system

TABLE V.

Comparative Pitch of Rifling adopted in English, Russian, Prussian, and American Guns of different Calibres.

Calibre of Gun, Inches.	English. One turn in Calibres.	English. One turn in Feet.	Russian. One turn in Calibres.	Russian. One turn in Feet.	Prussian. One turn in Calibres.	Prussian. One turn in Feet.	American.* One turn in Calibres Commencing.	American.* One turn in Calibres Ending.	American.* Ultimate Pitch in Feet.
2.50	30	6.25					68	34	7.08
2.70							70	35	7.87
3.00	30	7.50	35	8.75			72	36	9.00
3.15					47.12	12.25			
3.42			41	11.68					
3.50							76	38	11.08
3.54					52.04	15.31			
3.60	30	9.00							
4.00	35	11.66							
4.20			50	17.50					
4.50							86	43	16.12
4.71					60.17	23.46			
4.75	35	13.85							
4.80			50	20.00					
5.00							90	45	18.75
5.91					52.31	25.50			
6.00			60	30.00			98	49	24.50
6.30	40	21.00							
6.40									
7.00	35	20.41					106	53	30.91
8.00	40	25.00	60	40.00			112	56	37.33
8.27					58.85	40.17			
8.27					64.76	44.20			
8.27					67.76	46.25			
8.50			60	42.50					
9.00	45	33.75	60	45.00			118	59	44.25
9.45					62.39	48.66			
9.45					68.75	53.63			
10.00	40	33.33					124	62	51.66
10.24					70.00	59.15			
11.00					69.78	63.56			
11.00	35	32.11	70	64.17			130	65	59.58
12.00	35	35.00			70.82	70.82	136	68	68.00
13.00							144	72	78.00
13.05	54.79	59.58							
14.00					70.00	81.67	150	75	87.50
15.00							156	78	97.50

* The ultimate pitch here given is practically that adopted in this country.



10 Inch of 400 lbs. as fired at Fort Monroe

D. Van Nostrand, Publisher. New York.

and our own. It would seem at the outset a serious objection to any plan of rifling that it required a pitch fully double that found ample in other systems.

The extraordinary rapidity of the English pitch cannot, I think, be justified. If the rifling conveys rotation to the projectile *properly*, then we know that such rotation is excessive, because the Krupp guns excel in accuracy with only half this pitch; if, however, rotation is not properly conveyed, the plan should be abandoned. It can only be conjectured why the English have adopted so rapid a pitch. Beginning experiments with a very poor system of rifling and a uniform and moderate pitch, the result was unsatisfactory. The increasing pitch was then tried, with some improvement; but a majority of the shots having a "wobbling" and unsteady flight, indicating a want of steadiness in the bore, the angle of the rifling was greatly increased. The effect of this was to rotate the shot with such great rapidity that it had sometimes power to "recover itself"—*i.e.*, to *true itself*, or rectify an irregularity of movement which, in the first place, should never have obtained. Accordingly, the general accuracy was somewhat increased, and the pulsations of sound (by which an irregular flight is so readily detected), being so much more rapid, were less easily detected by the inexperienced and were less offensive to the educated ear. All this, of course, has been effected at a fearful sacrifice of wear and tear on the rifled surface of the bore, while there is ever present the disagreeable uncertainty as to whether the projectile and its studs, or even the gun itself, will stand the strains imposed.

It is difficult to understand why the question of at least the best ultimate pitch has not long since been absolutely determined; and although unsatisfactory systems of rifling and projectiles have, of course, interfered more or less with a practical solution of the question, still one would suppose that by this time there would be less diversity of opinion on the subject. Different projectiles require different forms of rifling, but there can be no good reason for two projectiles of equal size and weight having entirely different rates of rotation. With a reliable projectile and plan of rifling, the most suitable pitch should be easily determined; and a dozen old guns, rifled with a variety of twists (but on the same general plan), and fired a suitable number of times, each at the longest practicable ranges, would, I doubt not, afford a satisfactory solution of the problem.

I have already alluded to experiments recently made by the English "Committee on Explosives" with an 8-inch gun and different varieties of gunpowder. The velocities and pressures were ascertained at different points of the bore, as the projectile passed from the seat of the charge to the muzzle; and from the values thus obtained, time, velocity, and pressure curves were constructed,

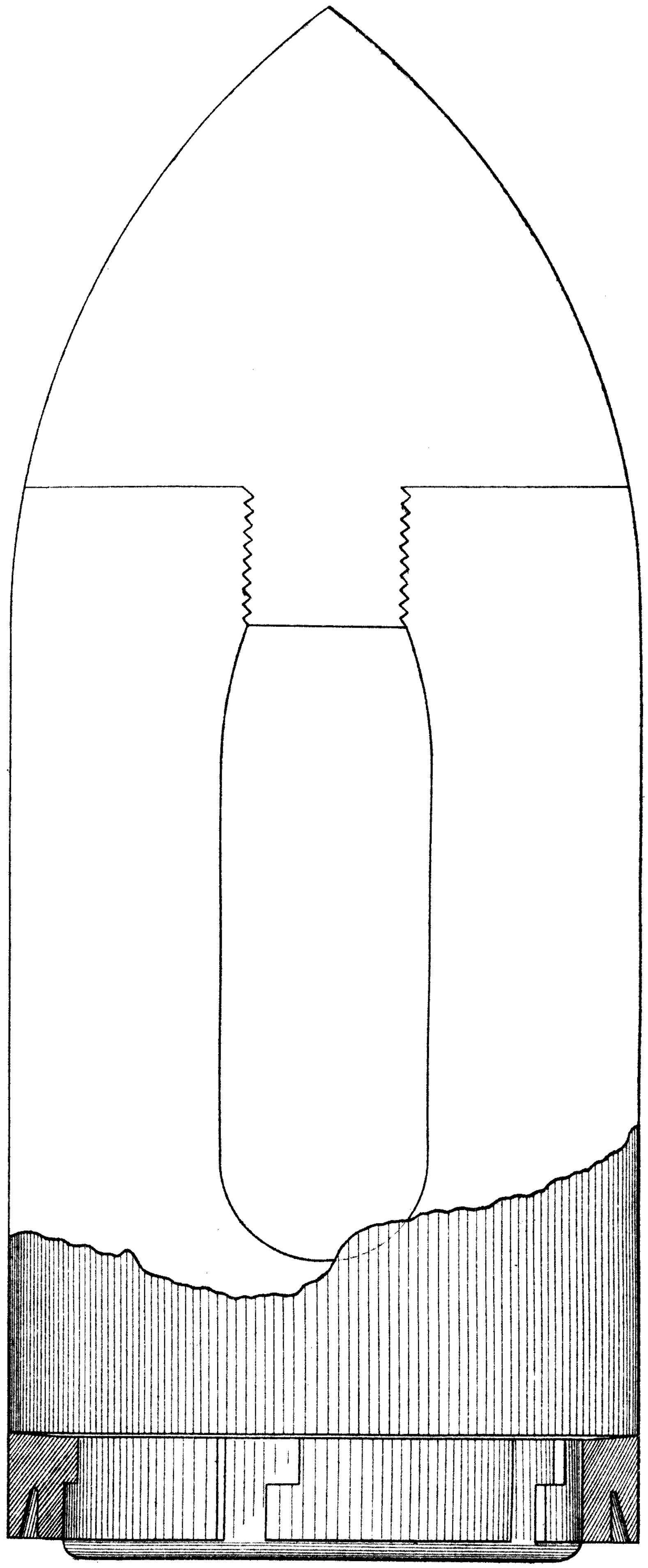
I have tabulated these curves below, and it is from this table that the velocities given in Table IV. have been taken. The following table, when scrutinized, reveals but trifling inconsistencies; and while the values given are not, of course, absolutely correct, yet the experiments were carefully and skilfully conducted, with the best available appliances, and it is thought that the inaccuracies are small. Even were these errors considerable, the results being relative, the table is of great interest, and is presented at this place as bearing intimately on the subject of rifling.

TABLE VI.

Tabulated Time, Velocity, and Pressure Curves, based upon Experiments in England by the "Committee on Explosives" with an 8-inch Rifle and four varieties of Powder.

Distance Moved by Shot, Inches.	R. L. G., 30 lbs.			Rus. Prismatic, 32 lbs.			Service Pellet, 30 lbs.			No. 5 Pebble, 35 lbs.		
	Pressure, Pounds.	Velocity, Feet.	Time, Second.	Pressure, Pounds.	Velocity, Feet.	Time. Second.	Pressure, Pounds.	Velocity, Feet.	Time, Second.	Pressure. Pounds.	Velocity, Feet.	Time. Second.
$\frac{2}{3}$	66,752			112			4,480			1,344		
1	61,600	300	.00025	448	20	.0035	9,856	90	.00075	4,584	40	.00175
2	41,216	410	.0005	1,568	55	.0056	23,968	180	.0012	15,232	125	.0026
3	37,184	475	.0007	3,584	80	.0066	34,944	280	.0014	25,088	220	.0030
4	35,168	530	.0008	9,632	130	.0070	38,528	375	.0016	30,688	300	.0033
5	33,600	580	.00095	35,168	230	.0073	38,528	450	.00175	33,600	375	.0035
6	32,256	625	.0011	45,696	345	.0076	37,184	510	.00195	34,496	445	.0037
7	30,688	660	.00125	43,680	430	.00785	35,616	560	.00215	34,496	495	.00385
8	29,568	690	.00135	39,200	505	.0080	34,272	610	.00225	34,048	540	.0040
9	28,224	720	.00145	35,843	560	.00815	32,704	650	.00237	33,152	590	.00415
10	27,104	750	.0016	33,600	605	.0083	31,584	680	.0025	31,256	630	.00425
11	25,312	785	.0017	30,240	660	.00845	28,896	730	.00265	30,688	675	.0044
12	24,416	820	.0018	29,120	700	.0086	27,776	775	.00277	29,568	720	.00455
18	19.712	925	.0023	24,640	855	.0092	21,952	900	.0033	24,416	865	.0052
24	16,576	1,010	.00285	21,504	965	.0098	17,472	990	.00385	21,056	970	.0057
30	13,888	1,075	.0033	18,592	1,050	.0108	14,784	1,060	.0043	17,920	1,055	.0062
36	11,872	1,130	.00372	16,128	1,125	.01075	12,768	1,125	.0048	15,456	1,130	.00665
42	10,304	1,175	.00422	13,664	1,185	.0112	10,752	1,175	.00525	13,216	1,190	.0071
48	8,736	1,210	.00465	11,424	1,235	.0116	9,408	1,210	.0057	11,200	1,240	.0075
54	7.392	1,240	.0051	9,408	1,270	.0120	8,064	1,245	.0061	9,408	1,275	.0079
60	6,272	1,260	.00545	7,616	1,300	.0124	6,832	1,270	.0065	7,728	1,305	.0083
66	5,152	1,285	.00585	6,048	1,325	.01275	5,600	1,295	.00685	6,160	1,330	.0087
72	4,032	1,305	.00625	4,704	1,340	.0131	4,480	1,315	.00725	4,928	1,345	.0091
78	3,248	1,320	.00665	3,472	1,355	.0135	3,472	1,330	.00765	3,920	1,360	.00945
84	2,464	1,330	.00702	2,576	1,365	.01385	2,688	1,340	.00802	3,025	1,370	.0098
90	1,792	1,335	.00742	1,792	1,370	.01423	1,792	1,345	.00842	2,240	1,375	.0102
96	1,120	1,340	.00780	1,008	1,375	.01460	1,344	1,350	.00880	1,792	1,380	.0106

To resume the consideration of the projectile: the new form is, I think, unquestionably well adapted to the larger calibres. Up to the present time but



12 Inch Projectile of 700 lbs. with steel head.

D. Van Nostrand, Publisher, New York.

a very limited number have been fired from large guns, but the admirable performance of these encourages me to believe that they will always be found to be thoroughly safe and reliable projectiles.

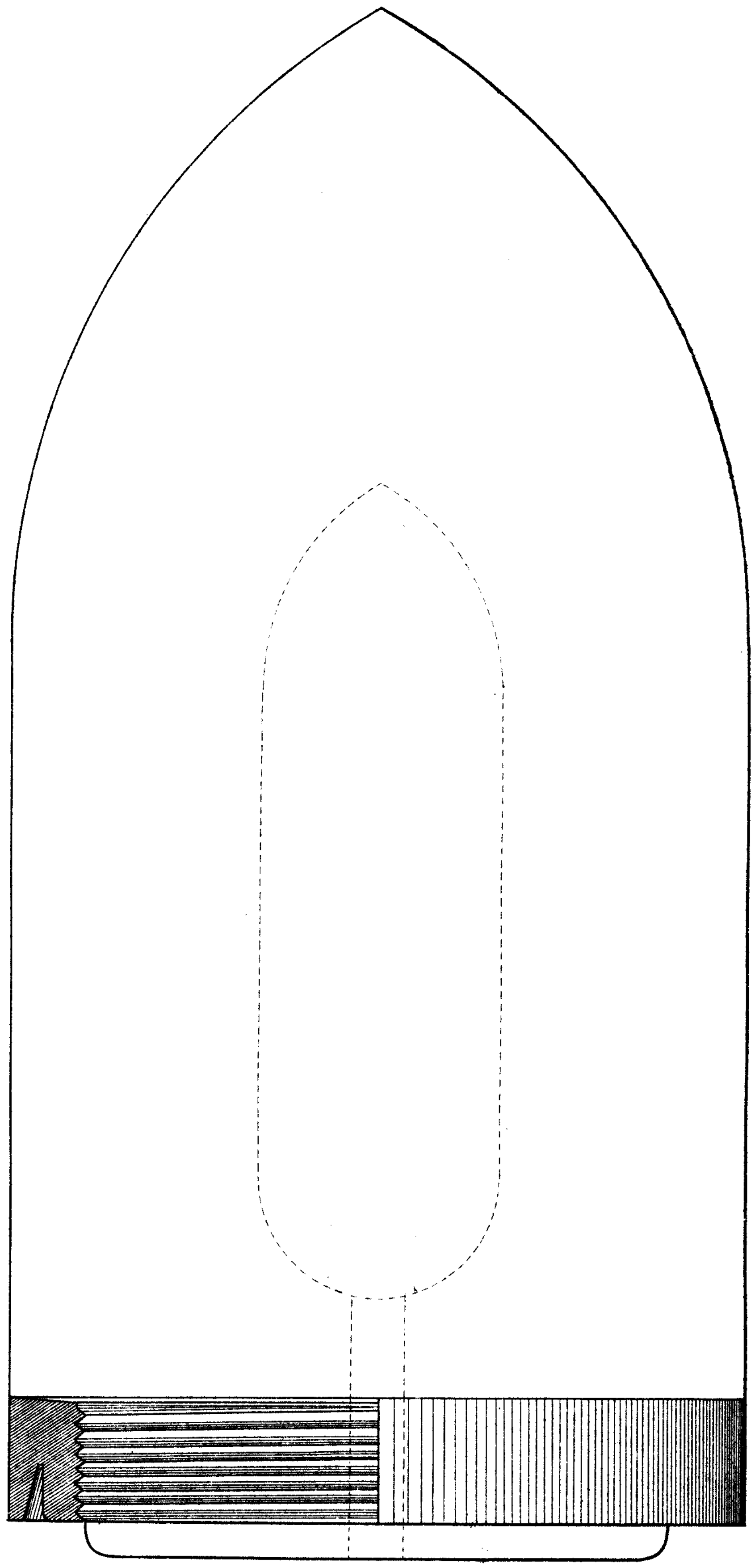
On Plate VIII. is illustrated a proposed siege-projectile; it may be of any suitable calibre, and is identical in principle with the field-projectile which has been described. The projection of the base of the projectile beyond the sabot is intended to guard against the injury of the latter in rough or careless handling. This is perhaps a needless precaution, as large projectiles are generally handled with care, besides which the sabot may be badly bruised (though it is not as susceptible to injury as either the lead-coated or studded projectile) without in any respect impairing its efficiency.

The bursting of the 12-inch cast-iron rifle at Fort Monroe left only a 10-inch Rodman rifle available at that place for the further prosecution of experiments with cake-powder; and, the Department having decided to use the new projectile, I received instructions to prepare the necessary drawings for their manufacture, and learned with some alarm that the projectiles were to be four hundred pounds in weight. Such a weight was one hundred pounds in excess of any 10-inch expansive projectile ever fired, at least in this country; and while I had full confidence that the sabot could be relied upon, I took the liberty to suggest, with the concurrence of Colonel Baylor, that inasmuch as the cored shot (which in the meantime had been sent to Fort Monroe to be finished) might be defective castings, or of a low grade of iron, there was a possibility, owing to their weight and length, of their crushing in the bore of the gun. Up to the present writing but few of these projectiles have been fired, yet I am gratified to state that although a velocity of 1,342 feet has been attained, the projectiles have remained so perfect as to be suitable for firing over again. This 10-inch projectile is shown on Plate IX. It will be seen that the sabot is screwed upon the base of the projectile. This plan was adopted, as affording a ready means of using the same projectile a number of times, simply by unscrewing the old ring after firing, and applying a new one, which may be made of old material. The projectile may thus be fired several times into the proof-butt before being so far injured by sand scouring as to render it unfit for further use. This method of attachment also affords an opportunity of inspecting the rings or sabots before applying them, and for service projectiles of large calibre it is thought that the plan may prove economical. For experimental projectiles the economy is, of course, great. Such an attachment is scarcely less secure than when the sabot is cast upon the shot with the usual dove-tails and undercuts. It might be supposed that the ring would be "set up" so violently in imparting rotation to the

projectile as to break the threads of the screw, or at least to bind so tightly as to render it difficult of removal. Experience has proved, however, that with the heaviest 10-inch shot the ring has not turned the tenth of an inch upon the projectile, even with the uniform pitch and high velocities. This would send the sabot forward something less than .001 of an inch. The sabot may be attached in various other ways. For small calibres, the projectile may be cast upon the ring which is placed in the mould in place of the usual sand core for creating undercuts, etc. In large calibres this cannot well be done, but the ring may be cast upon the heated projectile, if the best qualities of copper and spelter be employed. The ring may also be forced on by hydraulic pressure, or it may be locked upon the projectile mechanically. These various methods of attachment are illustrated in the accompanying plates, and there can be little doubt that all of them are secure. Different forms of double-lipped rings will be found on Plate XIV. Plate X. shows a 700-pound projectile, with a steel head, and having the sabot *locked* upon the base. It is thought that where difficulty might be incurred in producing the entire projectile of steel, the form here given, in which the head alone is steel, the balance being of good cast iron, might produce equally good and absolutely more uniform results than the solid steel projectile, which is liable to crack or to want homogeneity. Plate XI. represents a proposed battering-shot of 1,200 pounds for a 15-inch rifle. Such a projectile would carry everything before it. No necessity for its being made of any better material than a fair quality of cast iron. Plate XII. represents a proposed projectile for a rifled mortar. This projectile being fired at a high angle of elevation, and keeping parallel to itself through flight, will, of course, strike upon its base, which is accordingly made stronger than the front end. The centre of gravity, being to the rear, will also tend to make the shot fall in this position.

An objection which has been persistently, and heretofore with much reason, urged against expansive projectiles, has been their inability to sustain heavy charges. It will, I think, be manifest that this objection can scarcely obtain with the proposed projectile, as there is practically no limit to the strength attainable in its sabot, which is undoubtedly one of the strongest ever devised, and at the same time one which, while it may be made susceptible to the lightest pressure, is also abundantly strong to withstand the heaviest strains to be met with in service. It is thought that the new projectile may be made of almost unlimited strength, and that consideration for the gun alone need in future restrict the weight of either projectile or charge.

A proposed 12-inch projectile of 700 pounds is shown on Plate X., and, although I consider the weight to be excessive for the calibre, yet, as the



Proposed 15 Inch Projectile.

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English have fired this weight (although with indifferent success), and as Krupp proposes, I believe, to employ it also, I submit the propriety, when occasion offers, of firing a few projectiles of 700 pounds, confident that however objectionable such a weight may be on the score of efficiency and economy, the shot will not prove treacherous.

DOUBLE-BEARING PROJECTILES.

I have already given as my conviction that, by an allowance of a moderate windage or gas-escape over projectiles of the expansive class, they will be practically centered, or at least that balloting will be so far corrected that it can neither produce a marked irregularity of flight, nor still less to any extent injure or endanger the gun; and, although practical experiment with my projectiles at Fort Monroe has emphatically endorsed this theory as sound, without a single exceptional result to mar the record, yet I am not prepared to assert that projectiles of large calibre and maximum weight might not be benefited by a more substantial centering. On the contrary, I have long maintained the probable advantage of giving to our expansive projectiles a front bearing—centering the front as well as the rear of the shot, or *double-centering* it, so to speak, thereby securing beyond peradventure its passage through the bore without unnecessary jar or friction. To this end a number of plans have been devised and submitted, possibly the most practicable of which is shown on Plate XIII. The double-lipped expansive segments in the rear are expanded into the grooves in a manner requiring no explanation. The powder-gases escaping through the intervals between these segments, as well as over them through the unfilled angles of the grooves, is utilized in the expansion of a front series of segments, each of which is placed opposite a corresponding interval in the rear series. It is probable that we could substitute for the front series of segments the double-lipped ring, already proved so efficient on the rear of a projectile; but it is likely that a ring both front and rear would prove impracticable, for the reason that sufficient gas could not, perhaps, escape over the rear sabot to expand the ring in front, unless the latter were objectionably weak. As the segments are more readily expanded than the ring, it is possible that a ring in the rear and segments in front of the projectile might give satisfaction. The projectile on Plate XIII. would doubtless prove very accurate and give great uniformity of results.

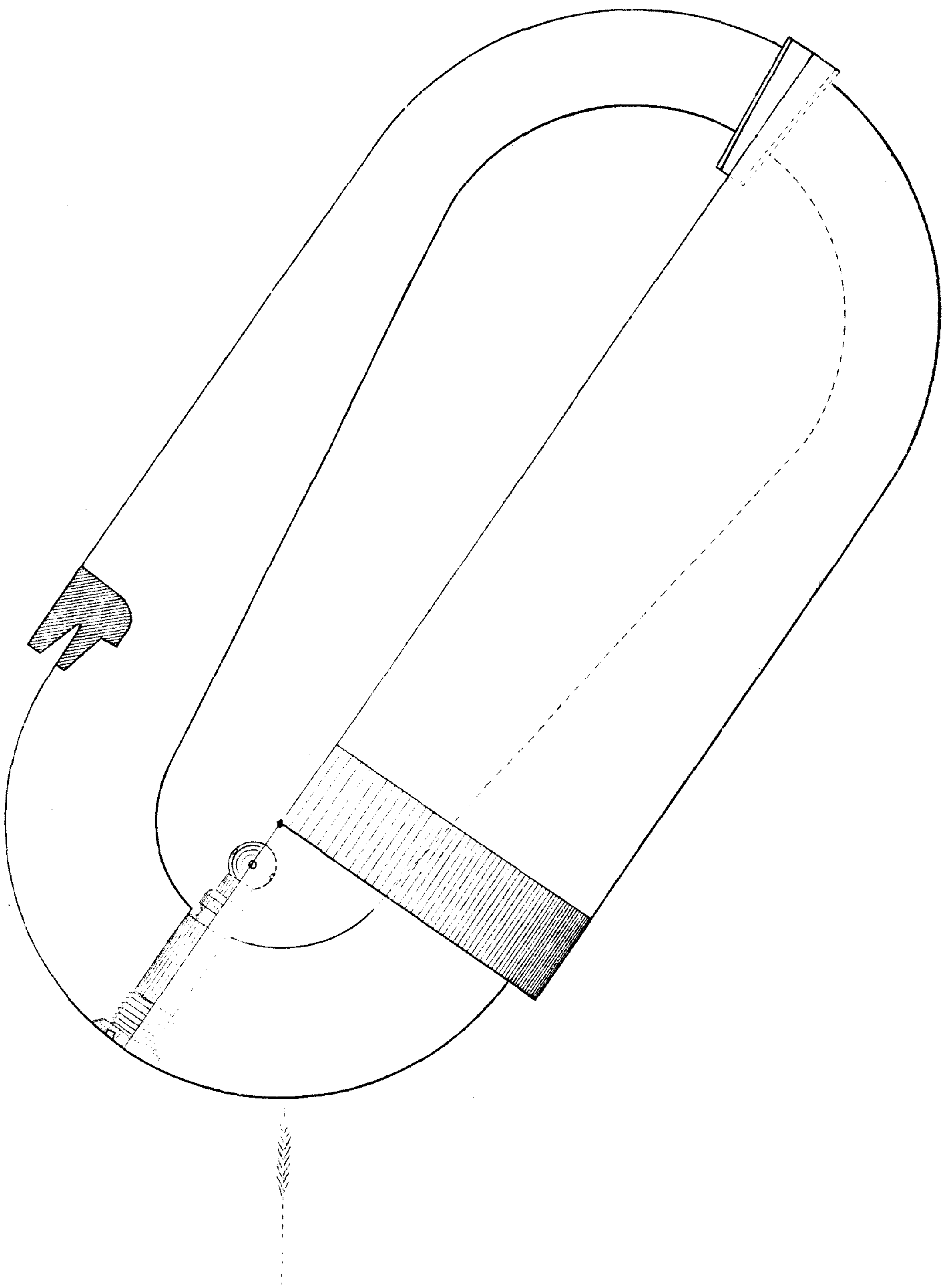
As already intimated, however, this projectile has been devised only with a view to supplying the wants of our expansive system in case the simple rear attachment should prove insufficient in any particular. Heretofore it has not

done so, even in systems of rifling by no means best adapted to it, and it is only a practical test which can ever determine the exact value of a double-bearing projectile of this kind, or its advantage over the simpler plan which has already proved so successful. It was, I believe, contemplated to test the value of this plan of "double-centering" in case the double-lipped ring proved inadequate for a 400-pound projectile, but the success of the latter, under all the disadvantages of a first attempt, dealing with unprecedented weights and charges, and without preliminary experiments with other than 3-inch projectiles, has, it is thought, rendered any experiment with the more complicated plan unnecessary. It might be interesting to observe, however, a close comparison of the pressures, velocities, and relative accuracy of these two plans of single and double bearing projectiles of the expansive class.

WEIGHT OF PROJECTILES.

As to what constitutes the correct weight for a rifle-projectile of given calibre, there exists great diversity of opinion. This is the more surprising as the problem would seem easy of a practical solution. Placing an iron target a few feet in front of a gun, firing at it with some shot of different weights, and selecting as the most suitable that which gives the greatest penetration and does not "wobble" too badly at moderate ranges, is an example scarcely worthy of our imitation. But if a series of rounds were fired from a gun of large calibre, with varying weights of charges and projectiles, making careful record in each case of pressure, velocity, range, accuracy, flight, and effect on gun and projectiles, one would suppose that from such data a correct judgment could be formed as to the most suitable weight of projectile for the particular calibre tested. Having ascertained this much, the weight of all other projectiles should sustain a similar relation to their calibre. The ratio thus established should never be widely departed from, and, consequently, *all demands thereafter made for increased weight of projectile should be met by a corresponding increase of calibre.*

The principal nations seem to have settled upon the most suitable weights for all *moderate* calibres, and to have agreed quite harmoniously on the subject. When it comes, however, to the question of heavy-armor punching, there has prevailed a tendency to increase the weight of the projectile without a corresponding increase of calibre, building the guns heavier to withstand the increased strains. In fact, the representatives of different systems would seem to have been engaged in a game of "brag," apparently vying with each other in the weight of metal to be thrown from a gun of given calibre, and it is there-



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fore not strange that the limit of practical utility and economy was soon passed, and that in consequence difficulties of great magnitude were encountered which proved serious obstacles to success.

While some men of scientific attainments have thus pronounced in favor of heavy projectiles, and have been tempted, I think, beyond the limit of sound judgment, others have persistently maintained the superior advantages of light projectiles impressed with high initial velocities. It is claimed, on the one hand, that the heavy projectile will utilize the full value of the charge by causing its more thorough combustion; that such a projectile will not only acquire a greater amount of stored energy than the lighter shot, but will maintain it better through a long flight. It is maintained, on the other hand, that every considerable increase in the weight of a rifle projectile of given calibre increases the chances of its misbehavior in the bore of the gun, reduces velocity, impairs accuracy, and augments the powder-pressure (independently of the increased liability of the projectile to wedge or jam within the bore), while the light projectile has free exit, is easily rotated, may be impressed safely with so high a velocity, by increase of charge, that its stored energy will practically equal that of the heavy projectile within ordinary ranges, and that, owing to flatness of trajectory, the lighter shot will be more accurate, and have a larger "dangerous space," in addition to which there will be less liability to failure of the shot or injury to the gun.

Having determined upon the most successful weights for projectiles of moderate diameter, as long as the difficulties of gun-construction increase in so rapid a ratio with the calibre, I maintain that it is unreasonable to fire from a gun of large calibre a shot which is heavier in proportion than that found most suitable for the smaller gun. When we are able to fire with invariable success, from any gun, a projectile nearly three times the weight of a spherical solid shot of equal diameter, with all the advantages of greatly superior accuracy, range, penetration, bursting capacity, etc., etc., I claim that we have accomplished all that it is reasonable to expect from such a gun, and that the problem of getting greater destructive effect has its natural solution in an increase of calibre.

Mr. Vavasseur suggests a formula for determining the weight of projectiles, $\frac{(\text{Diam.})^3}{2}$, but is himself guilty of inconsistency in departing from his rule in his proposed 10-inch and 12-inch rifles, where (perhaps in order to show no lack of confidence in his own system) he follows the lead of Woolwich, and proposes projectiles of 400 and 700 pounds respectively for the calibres mentioned. His formula, however, is a sensible one, and will be seen to correspond quite closely

to the standards adopted throughout the world up to a calibre of ten inches. At this point, however, a wide departure begins, and the weights for this and larger calibres pass far beyond the requirements of the formula. Applying Vavasseur's rule to various calibres, we have the following comparisons:

TABLE VII.

Weights of projectiles of different diameters, showing the inconsistency of present prevailing standard weights for large calibres.

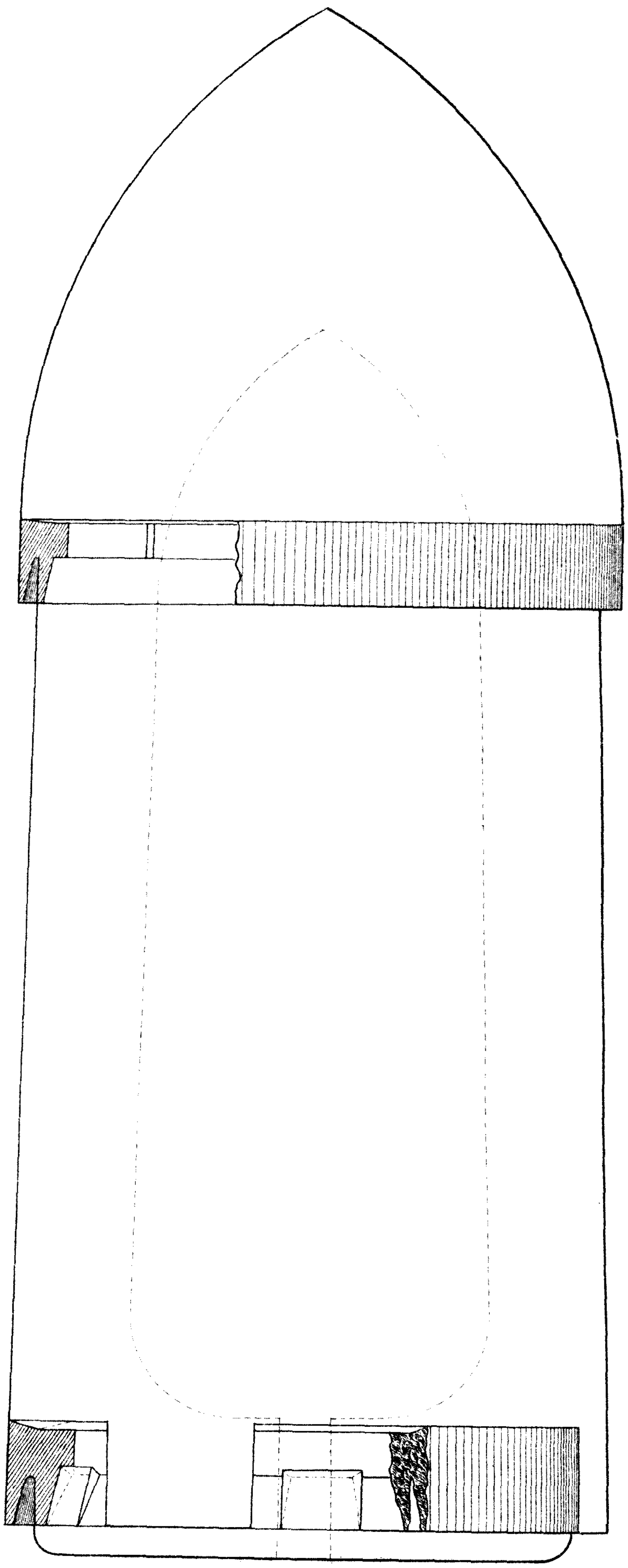
Calibres....	3 ins.	3.6 ins.	4.5 ins.	7 ins.	8 ins.	9 ins.	10 ins.	11 ins.	12 ins.
Standards..	9 lbs.	16 lbs.	30 lbs.	115 lbs.	180 lbs.	250 lbs.	400 lbs.	514 lbs.	700 lbs.
$(\text{Diam.})^3 \div 3$	9 "	$15\frac{1}{2}$ "	31 "	114 "	171 "	243 "	333 "	444 "	576 "
Difference..	0 lb.	$\frac{1}{2}$ lb.	—1 lb.	1 lb.	9 lbs.	7 lbs.	67 lbs.	70 lbs.	124 lbs.

This inconsistency cannot, I think, be justified, nor do I believe that it will much longer obtain. England, at the present writing, has but few guns of really large calibre; and her 10-inch projectiles of 400 pounds and 12-inch of 700 pounds, if anything more than experimental or "provisional," are scarcely entitled, by their present record, to be classed as service projectiles. Krupp is about completing a 12-inch rifle, the projectile for which, if I am correctly informed, will weigh something under 700 pounds. Prussia's heaviest service-gun at present, however, is a 11-inch rifle, the projectiles for which are of two weights, viz.: 404 and 515 pounds. The latter, although only for battering purposes and fired with prismatic powder, certainly appears objectionably heavy when compared with the $9\frac{1}{2}$-inch Krupp projectiles of 250 and 300 pounds.

I am by no means arguing in favor of light projectiles. On the contrary, those which I would propose as standards will be found, as a general rule, to exceed in weight those of corresponding calibre in Europe; but in the larger calibres of 10 inches, 11 inches, and 12 inches, I would avoid the inconsistency into which the English more especially appear to have been led. Our own projectiles (the few of larger calibre in service) have, as a general rule, been too light; for example, our 8-inch and 10-inch shot, weighing 150 and 260 pounds respectively; the great number of failures, even with such weights, indicating that any increase in weight of charge or projectile would have been attended with danger.

The great strength of the new projectile will, however, admit of our adopting any practicable weight. The application of the formula $(\text{Radius})^3 \times 2.80$ will

Plate XIII.



D.Van Nostrand, Publisher. New York.

be found, by reference to Table VIII., to correspond closely with the standard weights of projectiles in England, Russia, and Prussia up to a calibre of 10 inches.*

TABLE VIII.

Showing the comparative weights of projectiles in different countries, and a proposed standard.

Calibre of Gun in inches.	Weight, in pounds, of present Standards.				Proposed Standard. $(Rad.)^3 \times 2.80$
	English.	Russian.	Prussian.	United States.	
2.50	6				$5\frac{1}{2}$
2.70					7
3.00	$7\frac{1}{2}$ to $9\frac{1}{2}$	8 to 9		8 to 10	$9\frac{1}{2}$
3.15			9		11
3.47		13			
3.50					15
3.54			15		
3.60	16				16
3.67				20	18
3.75	20				19
4.20		34		25 to 30	26
4.50				30	32
4.71			32 to 35		
4.75	40				38
4.80		33			
5.00					44
5.91			60 to 68		
6.00		64			76
6.29	64 to 80				87
6.40	64			70 to 90	92
7.00	115				120
8.00	180	176		150	180
8.27			176 to 216		200
8.50					215
9.00	250	271			255
9.45			261 to 306		
10.00	400			250 to 300	350
10.24			350 to 412		
11.00		496	404 to 515		466
12.00	600 to 700		670	600	605
13.00	618				770
14.00			1000		960
15.00					1182

* Under no circumstances should a projectile exceed in weight three times the cube of its radius.

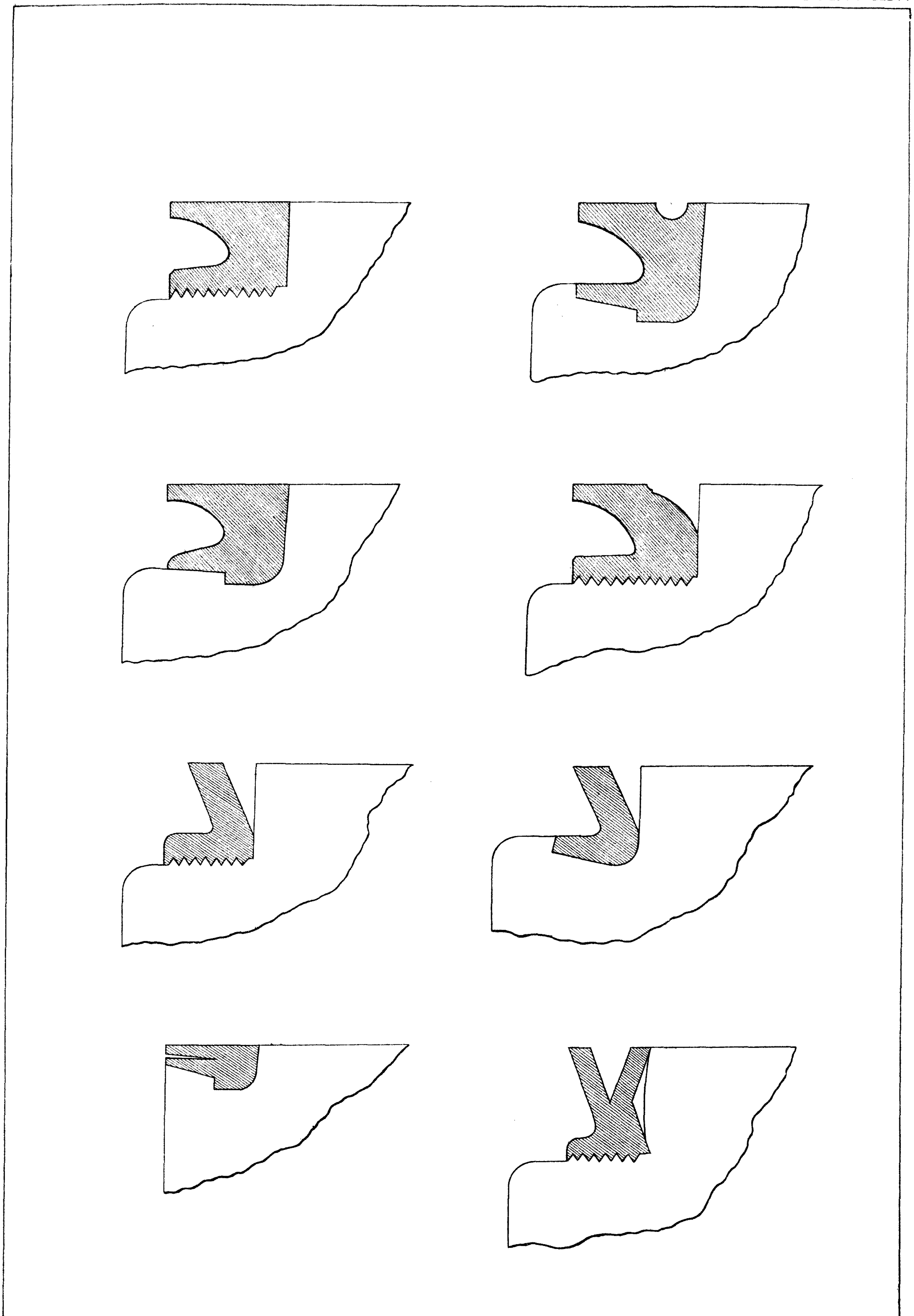
I maintain that no good reason can be assigned for departing from the formula (by *increasing* the weight of projectiles) just at the point where the difficulties and risks of gun-construction begin to increase in such a rapid ratio.

A few weeks since, on the receipt of instructions to prepare drawings for a 10-inch projectile of 400 pounds, I took the liberty to urge certain objections against the employment of such a weight, it being a hundred pounds in excess of any expansive projectile ever fired. One of the objections urged against the employment of a cast-iron projectile of this weight I beg here to repeat: "Crushing or breaking up the projectile in the bore of the gun. The action of the discharge upon each square inch of the base of a large projectile is the same as upon each similar superficial unit in a small projectile, while the 'column of metal' super-imposed upon each of such units is very much longer. From its own inertia cast iron cannot 'upset,' as wrought iron will do; but it can *crush* or *break* under sudden shocks, and its limit of endurance in this respect is not high. Sir Joseph Whitworth, having obtained authority to fire from a 9-inch Woolwich gun some projectiles of very superior iron and three calibres in length, found that out of three fired one broke up in the target and another in the gun; and, indeed, many instances can be given where heavy projectiles have so broken up even with moderate velocities. Now, as it is a primary object of these experiments to obtain high velocities, if possible, and as I have reason to fear that the iron in these last projectiles is of very indifferent quality, there is, I contend, danger of the projectile breaking up or crushing in the gun, and the hazard is further increased by the employment of a strange powder, entirely experimental, and very possibly treacherous."

A few of these projectiles have now been fired, and, I am gratified to state, with most flattering success. Still, the powder has thus far proved mild, and I cannot but fear, unless pains be taken in future to secure a good quality of iron, that, owing to some hidden defect in the casting, or to inferior grades of iron employed in a foundry inexperienced in the manufacture of projectiles, the consequence may yet prove disastrous to the gun, owing to the great weight of shot and charges employed.

In conclusion, I submit that, if it should ever be proved that projectiles of even 600 pounds can be more economically fired from a 10-inch rifle than from one of 12 inches calibre, our own system would be the best that could be adopted; and that if any projectile can be made to withstand such an ordeal, or that if any rotating device can prove equal to the work imposed, the double-lipped ring commends itself as most promising in point of strength, effectiveness, and easy action upon the walls of the gun. In fact, there is little doubt in

Plate XIV.



D.Van Nostrand, Publisher. New York.

my mind that our own plan of rifling and our expansive projectiles, as recently improved, constitute the most perfect muzzle-loading system in the world. Nor is this assertion so bold as may at first appear, when it is remembered that the comparison is necessarily restricted to the Woolwich and French "button" systems or to the *effete* systems of Jeffery, Thomas, Britten, Haddan, Scott, Whitworth, Lancaster, the "Shunt," and others, which have been discarded for the present Woolwich plan, or to equally faulty systems which have had their day in this country.

PART SECOND.

THE COMPRESSIVE SYSTEM.

(BREECH-LOADING.)

Projectiles of this class are necessarily confined to breech-loading guns, and, as the name of their class implies, take the grooves by compression. The one practicable method of effecting this, is the mechanical one of forcing the projectile through a bore of smaller measurement across lands than the diameter of the projectile itself. Hence it is necessary to coat the entire cylindrical exterior of such projectiles with a soft, compressible or yielding material, such as lead, so that the "lead-coated projectile" and the "breech-loading projectile" are now about synonymous terms; for, although we occasionally come across a lead-coated, muzzle-loading shot, it is generally among the "trophies" or relics of the past. Such attempts as may have been made to employ any other than compressive projectiles in breech-loading guns have hitherto proved failures; so that, with all its faults, the lead-coated projectile is at present an inseparable part of the best breech-loading systems of the day. Driven thus to employ a projectile which tested to the utmost the qualities of their guns, the advocates of breech-loading have found it difficult to hold their own even against the inferior muzzle-loading systems which have prevailed in Europe during the past few years; and were it not for the talent of Lewis Broadwell and the enterprise and immense facilities possessed by Herr Krupp, it is safe to say that the difficulties in the way of a satisfactory solution of the breech-loading problem would have proved an insuperable barrier to the extension of its principles so as to embrace the larger calibres. Furthermore, it is possible that, but for the introduction of Rodman's prismatic powder, Krupp's system, as applied to the larger calibres, would not be in existence to-day, or at least would be in far less efficient shape. In his competitive trial against the English 9-inch muzzle-loading gun, even after he

had copied the ogival form of the English projectiles, he was about prepared to give up the contest and acknowledge the superiority of the English rival, when the introduction of some prismatic powder from the manufactory in Russia saved the day to him, and proved, if not the salvation of his system as applied to heavy calibres, at least the foundation of his present success.*

Admitting the fact that for the same weight of material no breech-loader can be as strong as a muzzle-loader of the same calibre, it will be perceived how unfortunate it is for the breech-loader that it is forced to employ a projectile which, weight for weight of the same ammunition, will impose upon it vastly greater strains than those endured by the muzzle-loading gun. Add to this the fact that the pressure is further increased in the former gun by the necessary increase of charge to make up for the loss of velocity due to "forcing" the projectile, and we begin to perceive the full measure of one of the difficulties with which the breech-loading rifle has had to contend, namely, the faulty character of the projectile which it has hitherto been deemed necessary to employ.

I propose to deal with the defects of the breech-loading system only so far as relate to or are clearly attributable to its compressive projectile.

Holley, in his book on "Ordnance and Armor," briefly enumerates "some of the principal defects" of the compressive system, as follows:

"The principal defects of the compressing systems are:

"1. It unduly strains the gun by suddenly stopping all windage, by fouling, and by forcing the shot into a bore of smaller diameter.

"2. It reduces the velocity of the shot by compressing and fouling.

"3. The increasing twist is impracticable from the great length of soft metal coating.

"4. The soft-coated projectile is liable to injury in handling and in store.

"5. The windage is entirely stopped, thus increasing strain, possibly diminishing accuracy, and rendering the use of time-fuses uncertain.

"6. Soft coatings are liable to be so much loosened by the heat of molten metal that shell could not be charged with it."

To which may be added:

7. Stripping or losing the leaden jacket, or portions of it, in firing.
8. Reduced capacity for bursting charge.
9. "Leading" of the grooves.

* See Von Doppelmair on Experiments at Tegel.

Let us consider these objections in the order mentioned:

1. *Strains due to closing windage, fouling, and compression.*—The effect of closing windage by a lead sabot on the rear of a projectile has already been discussed. In the breech-loader, however, the projectile is centered, or approximately so, and the circumstances of its passage through the bore are very different. Under this head Holley says:

"The first result of a soft coating, whether it is expanded or compressed into the grooves, is stopping the windage. Gas which cannot escape without moving the shot may accumulate to a bursting pressure before the shot moves at all; whereas a safety-valve, in the shape of a thin, annular space around the shot, allows its inertia to be overcome before the pressure reaches the maximum, and a heavier charge—the burning of more powder after the shot has begun to move—will of course make up the loss of velocity with a less strain upon the gun, because it has more time to act. Thus all the advantages of slow-burning powder are realized." And again, from the same author: "But the chief strain due to lead coating is confined to the compressing system.* Forcing a projectile coated with hardened lead through a bore of smaller diameter, not to speak of compressing seventy-six grooves in it at the same operation, produces the following results:

"1st. A direct bursting pressure by the projectile itself. And compressing a lead covering soldered upon an iron shot, and very thin, so that it cannot expand longitudinally, is quite different from upsetting a leaden bullet, which simply changes figure in the same bulk.†

"2d. An increased powder-pressure, due to the detention of the shot by this stricture in the bore."

This second objection is unquestionably the more serious; but the first is also worthy of consideration. Captain Fishbourne, in the *Journal Royal United Service Institute*, 1864, says: "The pressure of forcing a 25-pound Armstrong shot slowly through the bore by mechanical means is said to have exceeded forty tons." I cannot but think that this statement is somewhat exaggerated; if not, the Armstrong projectile, still used to some extent in England, is even worse than I considered it. The statement would certainly be somewhat out of

* Omitting balloting and wedging, to which lead-sabot expansive projectiles are liable, this is doubtless true.

† Krupp has improved his projectiles in this respect by attaching the leaden jacket in a series of parallel ridges, or reinforces, so that the displaced lead may find room between the ridges.

the way as applied to Krupp's system. Nevertheless, the great loss of velocity due to "forcing" is good evidence of the severity of that operation.

2. *Reduction of velocity by compression and fouling.*—It seems to be generally acknowledged that the entire absence of windage conduces greatly to fouling, while "leading of the grooves" seems to be a chronic complaint attaching to the use of all lead-coated projectiles. How far this "leading" has been corrected I am unable to say, but I believe that the most successful preventive—plenty of lubricant—is more or less troublesome, and is good for only twenty-five to thirty rounds. Various French experiments have established the fact that closing of windage conduces greatly to fouling, and that, on the contrary, "the rush of gas over the projectile tends to relieve fouling by blowing out the dirt that would otherwise accumulate"—and whatever fouling may obtain, it must, of course, increase the friction of the projectile and reduce its velocity. It has been argued in favor of the compressive projectile that the gases of discharge being entirely shut off, the full benefit of the charge is thereby secured. The pressures, indeed, would indicate that such is the case; but we know, in fact, that the large Krupp steel guns suffer considerably from scoring at the seat of the shot. After the shot has moved forward so as to fill the bore, windage is of course closed.

"If it is important," says Holley, "to increase the pressure upon a shot, the use of more powder would appear to be a simpler and safer means than straining and abrading the gun by jamming a hard wedge through it. Besides, continuing to retard the shot by the friction of many grooves, and by an additional nip at the muzzle, after the pressure of the gas has been reduced by expansion, simply wastes power and reduces velocity without any compensation."

A primary condition of high velocity is "that the least possible power shall be expended in overcoming friction and changing the figure of the shot in getting it out of the gun. Power thus wasted is worse than lost, because it strains the gun so much as to require reduced charges, thus decreasing the velocity in another way. The service charge of the Armstrong 110-pounder has been reduced from 14 to 12 pounds for this reason." *

"So much power is expended in planing 76 grooves in a hardened lead-coated projectile that even 14 pounds of powder pressing on the 7-inch, 110-pound Armstrong shot give less velocity than 10 pounds of powder pressing on the Parrott 6.4-inch, 100-pound shot. The initial velocities are, respectively,

* Krupp has found a way out of this difficulty by the adoption of Rodman's perforated prismatic powder, where the quantity of gas developed increases nearly as the squares of the times of combustion. The same powder, used in a muzzle-loader, might give even better results.

1,211 and 1,244 feet, and the areas of the shot pressed by the powder are 38.5 and 32.1 square inches. The range of an Armstrong 7-inch, 110-pound shot with 12 pounds of powder was 3,387 yards, against 3,981 yards for the Jeffry 100-pound shot, same bore, charge, and elevation."

Some additional examples are given in the following table, compiled from "Ordnance and Armor":

TABLE IX.

Comparative velocities of breech and muzzle loading projectiles, with grained powder.

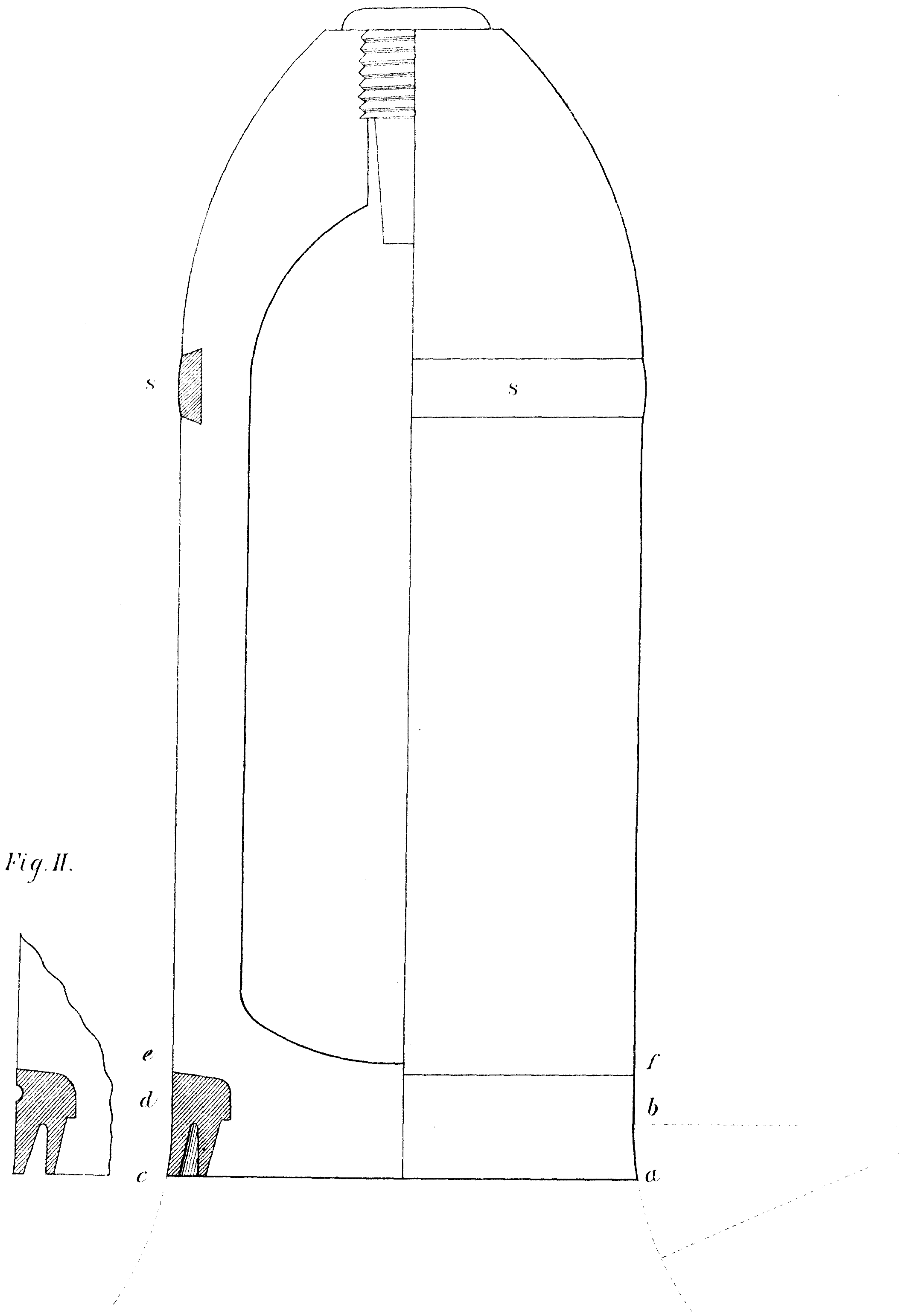
Name of System.	Diameter of Projectile.	Weight of Projectile.	Weight of Charge.	Velocity at Muzzle.	Relative Strength of Powder.
	Inches.	Pounds.	Pounds.	Feet.	Ratio.
Britten.....	6.24	50	5.00	1,213	1,170
Jeffry......	6.26	48	4.80	1,181	1,170
Hadden	6.19	54	5.40	1,123	1,170
Lancaster...	6.60	51	5.10	1,149	1,248
Thomas	6.25	57	5.70	1,277	1,248
French	6.36	65	6.50	1,148	1,248
Shunt......	6.32	55	5.50	1,172	1,248
Armstrong..	4.75	40	4.00	1,081	1,248
Armstrong..	4.75	41	4.10	1,051	1,248
Armstrong..	7.00	111	14.00	1,211	
Armstrong..	7.00	103	12.00	1,166	
Parrott	6.40	100	10.00	1,274	
Armstrong..	4.75	41	5.00	1,154	
Parrott	4.20	30	4.00	1,436	

It will be seen above that, even with the strongest variety of powder, the compressive projectile has much less velocity than any of the other systems—less even than the Shunt or French, notwithstanding the liberal windage of the latter; and that the comparison between the breech-loader and the Parrott gun is yet more strongly marked, although the brass ring of the Parrott projectile also allows considerable windage.

It is also objected to in the breech-loading system "that the rifle grooves have to be cut by the explosive force of the powder; and as this is done with immense velocity, and in the space of a few inches, the power required must be very great. The leading of the grooves and the stripping of the shot show how great this strain must be, and, in order to meet the difficulty and prevent such

Fig. I.

Fig. II.



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effects, recourse has been had to slow-burning powder, and, as a consequence, a low initial velocity has been obtained." * We must here again make exception in favor of Krupp's larger guns, where fair velocities have recently been obtained by the use of *prismatic* powder.

To compensate for this loss of velocity by compression and friction, increased charges of grained powder, when employed, have not given satisfaction, leaving out of question the increased pressure. It is stated that "if the lead is put on evenly, as in some projectiles, in a thin form, and you pass one-eighth the weight of projectile as a charge, the lead is given off from the projectile on the discharge of the gun in the shape of an amber-colored cloud called 'lead fumes'; and that if you exceed a charge of one-eighth, and go to the charge of one-fourth, you are exposed to another source of inconvenience—the positive *melting* and remaining of the lead in the bore of the gun. This is a result of experiments at Shoeburyness alluded to by Colonel Lefoy."

To remedy as far as possible the defects already mentioned, the leaden jackets covering Krupp's projectiles are provided, as has been stated, with reinforces of lead in the shape of a number of parallel rings. No doubt this is an improvement, but at best it can be expected to remedy the defects of the system only in part. I have not available, at present, what I should consider authentic and reliable accounts of experiments with Krupp's large calibres. Some reports are highly colored, while other and more recent reports speak either of a burst gun or of "unsatisfactory practice with moderate charges," and the "occasional loss of the leaden jacket" when heavier charges are attempted.†

There can be no doubt, however, that since the introduction of prismatic powder Krupp has been making rapid improvement. He has already attained high velocities, which he could not do with grained powder without enormous pressures; he has greatly exceeded the English in accuracy, at least for moderate calibres; and his projectiles are less liable to strip than formerly. They are by no means perfect as they should be, however, and he is constantly experimenting to improve their quality. There is little doubt in my mind that the breech mechanism of his guns is strained unnecessarily by the character of the projectiles employed.

For the same charge and kind of powder,‡ weight and calibre of projectile,

* Mr. Michael Scott on "Projectiles and Rifled Guns."

† Report on the Fabrication of Iron for Defensive Purposes. Professional Papers, No. 21, U. S. Engineers. 1870.

‡ As has been stated, the introduction of prismatic powder has enabled Krupp to obtain high veloci-

the compressive projectile will have much less velocity, giving much greater powder-strain than either the French-Woolwich (stud) or the expansive systems. To bring up the velocity, therefore, increased charges must be employed, and here again the breech-loader, through its unfortunate projectile, must incur far higher pressures with less compensating effect than would its rival systems, which are at the same time better able (if of same weight and material) to endure the unusual strains.

3. *Increasing twist impracticable with compressive projectiles.*—This is owing, of course, to the great length of bearing of the rifling upon the leaden jacket, which would be stripped from the projectile before it would accommodate itself to the changing angle of the pitch—if, indeed, it did not jam in the gun and burst it. And yet, of all systems, the breech-loading is the one which seems absolutely to *need* the increasing pitch. In the case of muzzle-loading guns, I conceive the chief argument in favor of the uniform pitch to be that as the projectile starts at 0, and moves a certain distance before attaining a high velocity, therefore this seems an auspicious time in which to impart to the projectile *some* of the rotation which it must acquire before leaving the gun. With the breech-loader, however, the case is reversed—the projectile being loaded in an unrifled chamber, and only its front end being in contact with the rifling (whereby it is detained until a high pressure is reached), the projectile is absolutely dashed into the rifling with considerably velocity; hence must be imparted to the projectile almost immediately the full value of the twist, whereby will result increase of pressure, diminished velocity, and increased tendency to strip the projectile and "lead" the grooves. Could an increasing pitch, however, be employed, its full value would be communicated to the projectile throughout the bore of the gun, after a fair impression of the grooves had been taken in the first instance. Yet how impracticable to employ such a pitch with the present lead-coated projectile!

4. *Liability to injury of lead-coated projectiles in store and handling.*—The great extent of the lead-coated surface, and the soft quality of the material, render compressive projectiles peculiarly susceptible to injury from rough handling, transportation, etc. "The heavy projectiles required in naval and sea-coast warfare are constantly liable to such falls and rough handling as would be quite sufficient to upset a soft coating, and prevent its entrance into either a breech-loading or a muzzle-loading gun." * When such injury is very marked, the pro-

ties without incurring heavy pressures. It remains to be seen whether the use of prismatic powder in muzzle-loading guns will not place them again in advance of breech-loaders *employing lead-coated projectiles.*

* Holley.

jectile could be set aside without waste of time. The more serious case would be that when, in the heat and hurry of action, a projectile should be just sufficiently dented to cause delay from binding or jamming in loading.

Lead-coated projectiles are liable to other kinds of injury. It has been remarked * that "they will decay from damp; and those in store are decaying and the lead exfoliating. Many of you are aware that Lord Clyde sent home some bullets which could not be got down into the rifle at all; the lead had exfoliated, and the bullets were too large, and at Delhi several of our men were shot down while trying to force bullets down the bore of their rifles." †

It is fair to say that I attach not too much importance to this last statement; and while it is undoubtedly the fact that the lead-coated projectile is more susceptible to injury than any other, yet I regard this as one of its minor defects. Whether or not the mechanical union of the lead jacket with the iron shot would in time become loose I am not prepared to say. The Prussian projectiles have to be handled with the greatest care, the larger sizes being boxed separately in shavings, and the field-projectiles kept from contact with each other by iron stirrups, or clamps, and thumb-screws in the ammunition-chests.

5. *Closing of windage.*—The increase of strain resulting from the closing of windage has already been discussed. There are, however, other consequences to be considered. It is next to impossible to use the ordinary and more simple form of time-fuse—namely, that which is ignited by the flame of discharge—and, consequently, "a more complicated and costly fuse must be employed, with probably increased uncertainty of ignition." "In the case of the Armstrong gun," says Holley, "this has led to costly and nearly fruitless experiments with percussion-fuses." The same difficulty was incurred by us in the use of soft-sabot expansive shells, and the case was successfully met, I believe, by the Laidley igniter, which would probably prove equally efficient in compressive projectiles. Hence this objection to the absence of windage I cannot regard as a serious one. How far accuracy might be promoted by a moderate allowance of windage it is difficult to say; in all other systems it has proved advantageous in this respect. "The result of the more recent experience of the French artillerists proves that the suppression of windage diminishes the accuracy of fire." ‡ It is probable, at all events, that the accuracy of a breech-loader would be promoted to just the extent that fouling would be prevented. That windage tends to prevent fouling

* *Journal Royal United Service Institute.*

† Is it not probable that these bullets left the cartridge-factory in England just as large as they returned?

‡ *Edinburgh Review*, April, 1864.

seems to be a well-established fact. "The rush of gas over the projectile tends to relieve fouling—to blow out the dirt that would otherwise accumulate." So far as windage may operate as a "safety-valve" for the moderation of pressure, it is also important for large guns.

6. *Use of molten metal.*—"One of the requirements," says Holley, "of modern shells, is to fire molten metal. Even if the heat of the molten metal does not loosen the lead, the expansion of the shell vastly increases the strain in forcing an Armstrong shell through the bore." Commander Scott says: "One of the most important things, that has been very much overlooked, is that of molten iron. The molten iron will fill up the shell and make it almost solid, so that you will at first have the full blow of the molten iron, and, unlike powder, the molten iron, if you can pitch it against anything, will stream over it; it may stream into the port. This will be found, I believe, a fearfully destructive weapon. The Armstrong gun" (any breech-loader) "will not throw it; that is, practically it will not do it. The small, round shell contains too small a quantity to be effective. What we want is a large quantity; but even the less quantity sufficed to set a vessel on fire; and when it was tried, although they had the engines and everything ready, as is well known to Admiral Halstead, they could not put the fire out."

Although shells for molten metal have usually been made with thin walls to facilitate their breaking up on striking wooden vessels or other light resisting objects, I see no reason why they could not be employed with some effect against iron clads, at least of the lighter class, if made with thick, strong walls and fired from the heavier calibre of rifles. The iron plates being penetrated or even cracked, and the shell broken, the fluid iron might find its way to the wooden backing or decks, and any fire resulting therefrom would be difficult to extinguish.

Whatever the efficiency of molten metal in warfare, it is clear that if it is not absolutely impossible for the present breech-loading projectile to be charged with it, its use in such projectiles must, at least, be attended with difficulty and danger.

7. *Stripping.*—This is an evil which, up to the present time, has never been wholly overcome in lead-coated projectiles, and yet is a fault so serious as to be sufficient, in my judgment, to condemn any projectile in which it is even remotely liable to occur. As late as 1871 we read of the "occasional loss of the leaden jacket" in practice or experimental firing in Prussia.

8. *Reduced capacity for bursting charge.*—This objection applies more particularly to field-projectiles. The relative capacity of the Prussian 3.15-inch field

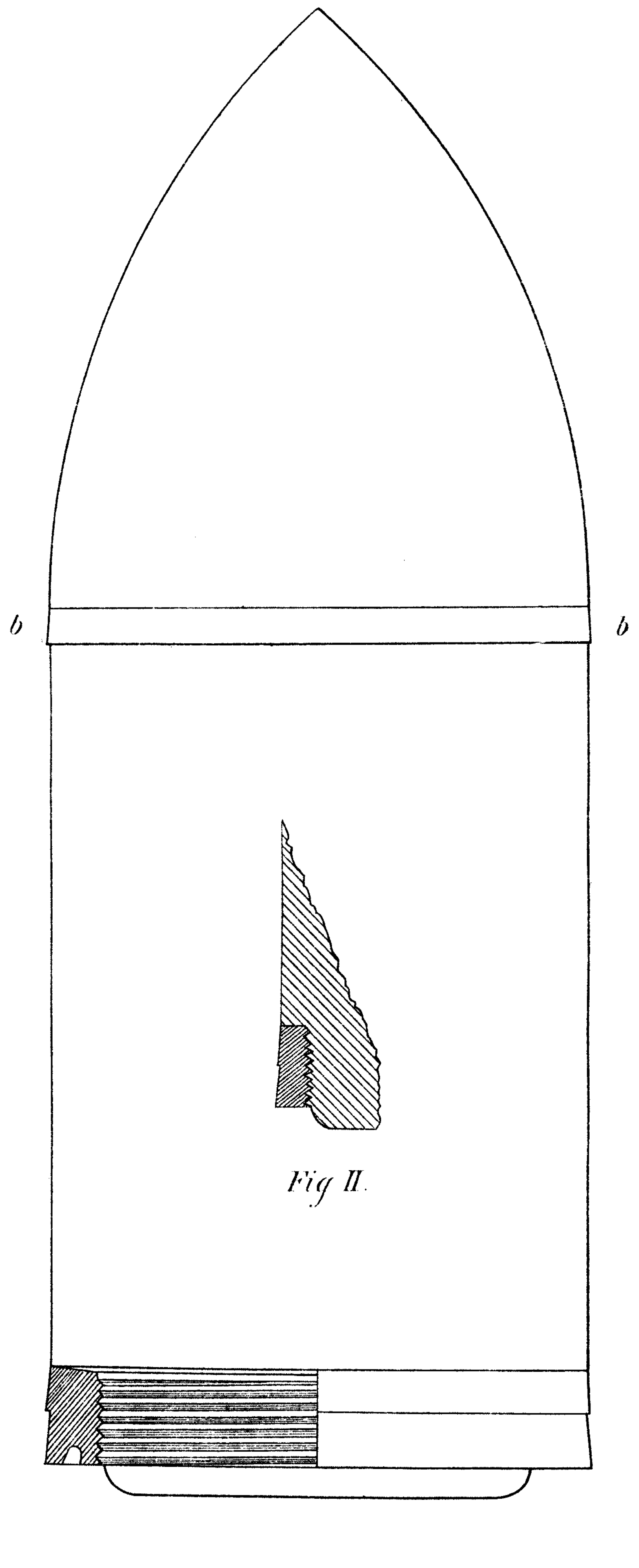

Fig II.

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shell to our own 3-inch field-shell is about as three to four; and the same ratio will hold good for case-shot. The weight of the leaden jacket, which is usually about one-tenth that of the entire shell, is just so much deducted from the capacity of the latter; and it is further limited in length by the principle of its action in the gun. If the lead bearing is too short, it is inefficient; and if too long, the friction becomes so great * as to reduce vastly the velocity.

9. *Leading of the grooves.*—The co-efficient of friction for a bearing of lead upon cast iron, wrought iron, or steel is greater than for that of almost any other two metals; and, while friction is to a degree independent of velocity, it is not so unless unguents are used, and it increases very decidedly, in some contacts, with an increase of temperature. When we consider the great force necessary to compress many grooves into the leaden jacket of a breech-loading projectile, the infinitely small time in which it is accomplished, and the enormous velocity with which it is driven through the gun—tightly compressed meanwhile—and that great heat must be thereby developed, independently of the heat of discharge, it is not surprising that every effort heretofore made to prevent the leading of the grooves by compressive projectiles should have failed, except, perhaps, when accompanied by circumstances equally objectionable. In the slow and deliberate experimental firing at Essen, and in spite of the liberal use of a lubricant, Krupp's guns have to be tediously scraped to free the grooves from obstructions at least every thirty rounds. In rapid field-firing it is almost a fatal objection; and to the leading of the grooves may be attributed the disabling of many guns. In the *Russian Artillery Journal* may be found complaints of the "severity of the two or three hours' labor, after a hard day's marching and fighting," of putting the breech-loading guns in serviceable condition again by "unleading" the grooves.

PROPOSED SYSTEM OF BREECH-LOADING RIFLING AND PROJECTILES.

Having thus briefly discussed some of the principal defects of compressive projectiles, I shall proceed next to a consideration of the manner in which it is proposed to remedy their faults, and yet to retain, as far as possible, in full measure the chief advantages of the best of their kind, namely, accuracy and the absence of balloting; both resulting from the fact that they are centered, or approximately centered, as the longer axis of the compressive projectile is of

* It should, of course, be borne in mind that friction is only independent of the surfaces pressed when such surfaces of contact are theoretically perfect. Besides, the greater the length of the lead-jacket, the more danger of its folding upon and wedging the shot, especially in large guns.

course placed and held in a position nearly coinciding with the axis of the bore. I have also to propose certain modifications in the rifling and chambering of the gun, which, in connection with the new projectile, will, I think, constitute a system superior to the lead-coated systems of Krupp and Armstrong.*

The proposed breech-loading projectiles are illustrated on Plates XV., XVI., XVII., XVIII., and XIX. On Plate XV. is shown a field-projectile. The double-lipped ring or sabot is here seen to be almost identical in form with that already fully described in the class of muzzle-loading expansive projectiles; the only difference, in fact, is in the slightly-increased diameter, *c a*, tapering to the true diameter of the projectile at *d b*. On the front of the projectile is a light band of lead, *s s*, secured by undercuts in the projectile, and having a superior diameter, slightly exceeding the bore of the gun, though somewhat less than the diameter, *d b*. Instead of this leaden ring, however, I would prefer to use a delicate bevelled ring of soft brass (Plate XVI.), having a superior diameter, *b b*, very slightly exceeding the diameter of the bore; or, in large projectiles, when it may be thought desirable to allow more windage, the bevelled segments, *s s*, shown on Plate XVII., might be employed to advantage.

Operation.—To those familiar with the subject the operation of these projectiles is obvious. It has already been explained that the sabot may be so arranged by properly limiting the length and thickness of the upper lip that under the heaviest pressures that part of the sabot will not be set up into the grooves any further than desirable towards the line *e f* (Plate XV.), and that, consequently, the junction of the two metals along that line will be as smooth and perfect as before firing; in other words, the impression of the rifling deepest at *c a* upon the upper lip *runs out* about at *d b*, or disappears a little beyond that line. To explain further—conceive any ordinary expansive sabot to be operated upon by the discharge. If of soft metal, it will be set up equally along the line *c d e*, and there will, consequently, be a shoulder at the junction of the sabot and projectile proper; that is, the soft metal will rise above the surface of the projectile along the line *e f*. If the sabot is a ring or band of brass or hard metal, intended to be expanded by the entrance of gas between the sabot and the iron body of the projectile, the same thing will obtain. (See Fig. 2, Plate I.) If a cup be driven upon a conical base, we have a like result; and taking the concave disk, the same thing will still obtain. Suppose any such projectile to be fired from a breech-loading gun, the sabot being freely expanded in the chamber would, of course, provide a shoulder along *e f* to be nipped by the grooves with

* The breech-loading *stud* system, which is an outgrowth of the dissatisfaction prevailing with regard to the compressive lead-coated system, I have not thought it worth while to discuss.

the absolute certainty of being stripped from the projectile, as the latter was being forced through the rifling, with ample opportunities of wedging in a manner most objectionable.

Let the projectile on Plate XVII., however, be inserted in a breech-loader, and pushed forward in the chamber in the same manner as the ordinary lead-coated shot, until the bevelled segments on the front of the projectile stop against the rifling at the head of the chamber; the front end of the projectile is by this means centered. The first effect of the discharge is to expand the upper lip to the full diameter of the chamber with great evenness and uniformity, as experience has proved, thereby centering the rear of the projectile, the front of which is already centered in the rifled portion of the bore. The projectile being thus accurately centered in the chamber, its axis coinciding also with that of the bore, it is launched straight through the latter on its path. It has already been explained that the sabot will never rise above the surface of the projectile along the line *e f*; consequently, the upper lip, being expanded to the full diameter of the chamber, will present a *tapering surface* toward the rifling of the gun, which itself forms a bevelled junction with the chamber. As the projectile, therefore, is forced into the bore, the expanded upper lip is compressed by the rifling, and the impression of the lands is thus made upon it. Now, if the sabot were solid and rigid, instead of being grooved and yielding, we would lose much and gain nothing by the substitution of brass or copper for lead, except that there could be no leading of the grooves; and unless the bore tapered slightly towards the muzzle, thereby increasing friction, the projectile would become looser and looser as it made its way through the gun. Instead of this, however, as the projectile is forced into the rifling, there is a yielding and elastic cushion of gas under the distended upper lip, which not only limits the wedging strain upon the gun, but keeps the upper part of the sabot distended throughout the passage of the projectile in the bore, whereby the projectile is not only kept accurately centered, but any chance inequalities or obstructions within the gun will be readily passed over, owing to the yielding but elastic character of the contact. The front part of the projectile is centered, of course, by the front bands or segments, which should be of such diameter as to take but a faint impression of the rifling—just sufficient, in fact, to secure a good bearing. This bearing will be good throughout the bore, for there will be just sufficient "slip" of the sabot from the attrition of the edges of the grooves upon it to keep the various points of contact of the front bearing always fresh and tight. For the reason that the yielding of the upper lip limits and controls the wedging force of this projectile, it is practicable to ensure the perfect centering and constant

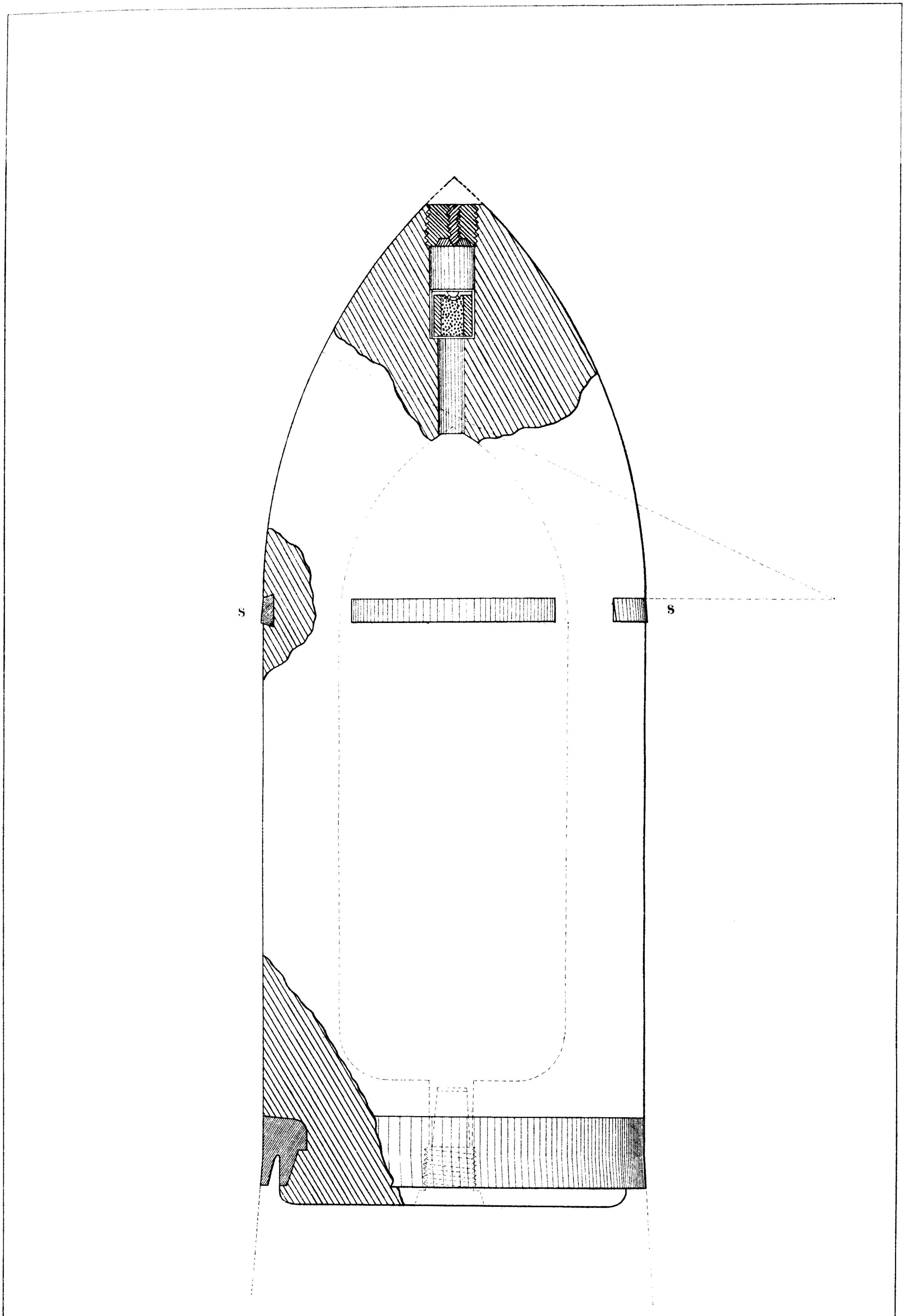
contact of the front bearing by a very slight contraction of the bore toward the muzzle. I maintain that such an expedient would be devoid of all hazard with this projectile, but not so with the ordinary lead-coated shot. It is clear, also, that the usual narrowing of the grooves toward the muzzle will not be necessary or even advisable with the expansive projectile. If the sabot be grooved, as shown in Fig. 2, Plate XV., it will be impossible for any of the solid, non-expansive portions of the sabot to take even a faint impression of the rifling.

Instead of the bevelled ring or segments or the leaden band already described, the front part of the projectile may be provided with a soft brass or copper wire, as shown at *s s* in the figure on Plate XVII. The wire could be very readily attached in an annular groove in the projectile, and I doubt not that a number of such wires encircling the projectiles at different points throughout its cylindrical length would give results in some respects superior to the lead-coated projectile, although, like the latter, it would not enter the chamber absolutely true, and is objectionable on other accounts.*

For a non-expansive projectile I would prefer that shown on Plate XVI., having parallel bevelled rings of soft brass or copper, front and rear. Any number could be applied, but two or three would no doubt be sufficient. The rear ring could either be solid or slightly grooved, as shown in the drawing—not for expansion, but simply to facilitate compression of the rear band, upon which is devolved most of the work of rotation. With such projectiles it might be advisable to taper the bore of the gun very slightly toward the muzzle, in order to ensure a continuous bearing throughout. But, as I consider this objectionable, I need scarcely say that I prefer the designs given on Plates XV., XVII., and XVIII.

One other breech-loading projectile remains to be described, and it requires no better illustration than is given in Fig. II., Plate XIX. It is simply the expansive breech-loading projectile previously described, without the front centering, or bearing, rings or segments. The admirable practice with the muzzle-loading expansive projectiles, constructed on a similar principle, gives good assurance that when a moderate windage obtains over the projectile, as has been explained, no front bearing is necessary. In the case of the muzzle-loader, the upper lip of the sabot is quickly and evenly expanded, and the escaping gases are thereafter distributed uniformly about the projectile; but in the case of a breech-loading projectile, like that in Fig. II., Plate XIX., the gases are evenly dis-

*Since the above was written I have seen reference to experiments with projectiles of this character. This suggestion of the copper wires is therefore anticipated.



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tributed *from the start.* The outward flare of the upper lip serves as the necessary *stop* for the projectile against the bevelled junction of the rifling and the chamber (the body of the projectile resting in the rifled portion of the bore); and fine practice having been obtained with a muzzle-loader, I see no reason why equal, if not superior, results might not be obtained from a breech-loader properly rifled and served with these projectiles.

In such a system the length of the rifled part of the bore is increased by the cylindrical length of the projectile, or the gun may be shortened to a like extent; the chamber is shortened by one-half, and may be more easily kept clean; the projectile may be more easily inserted, with less danger of sticking owing to foulness, since the chamber may be of much greater diameter than the bore; we are not restricted as to the character of the pitch; and, finally, any desired length of projectile may be used without altering the powder-space behind it.

The Rifling.—The general character of the rifling in breech-loaders consists in a great number of shallow grooves, usually narrowing toward the muzzle, to make up for the slip and abrasion of the leaden jacket of the projectile. The bore has also sometimes been contracted toward the muzzle to accomplish the same purpose. Neither of these measures is necessary or advisable with the projectiles just described, which would doubtless, however, give more or less satisfaction with almost any form of rifling, unless, indeed, the grooves were very few and rounding.

When the short chamber is employed, and the projectile has no front bearing, I would propose identically the same rifling as that suggested for muzzle-loaders, and described in the first part of this report. But when the long chamber is used, it would probably be advantageous to increase slightly the number of the grooves, but in no case to remove much more than half the original surface of the bore in rifling; in other words, the width of the grooves should not exceed but little, if at all, that of the lands. The narrower the lands and the wider the grooves, the more sharply will the former impress the upper lip of the sabot, as it passes through the bevelled shoulder of the rifling; but the bore would be more liable to injury, and especially by the use of canister, which would be impracticable if the lands were very delicate. For example, a 3.5-inch gun, with sixteen grooves, the lands being each 0.2-inch wide, would undoubtedly give great accuracy of fire; but eleven lands, each 0.45-inch wide, would doubtless yield equal accuracy and much greater endurance.

In the bevelled junction of the rifling and chamber for these projectiles I also propose a modification. Figs. 1 and 2 on Plate XIV. show the ordinary ramps, so to speak, which lead from the chamber to the tops of the lands or

surface proper of the bore. The chamber is always the full depth of the bore, plus that of the rifling, and in large calibres something over. I propose for a double-bearing projectile that the chamber be equal in diameter to the bore, plus *half* the depth of the grooves. For the same length of ramp, therefore, the ascent will be easier, while the projectile will be just as easily inserted in the chamber as is the expansive projectile in the muzzle-loading gun; and at the same time the *flare* of the upper lip may be reduced. The figure on Plate XVIII. illustrates this form of junction, which I consider is well suited to either the double or single bearing projectile. For the latter, however, the chamber may be of almost any desired diameter; and it will be found a great advantage, probably, to have the diameter considerably larger than the bore, as the projectile may then be readily loaded, and fouling of the chamber will be less an obstacle to the insertion of the projectile.

It has sometimes been the practice in breech-loading guns (at least the attempt has been made) to form the chamber of two diameters. The part next to the bore for a distance equal to the cylindrical length of the projectile is made to exceed slightly the diameter of the bore; this we might term the shot-chamber. Back of this there is the powder-chamber, of yet greater diameter, the powder-chamber being connected with the shot-chamber, and the latter with the bore of the gun by the appropriate ramp or bevelled surface, usually the frustrum of a cone. It is obvious that such a form of chambering is well adapted to the proposed double-bearing projectile, since the shot-chamber, and the ramps connecting it with the powder-chamber and the bore respectively, may be so arranged as to accurately centre the projectile in the operation of loading. (See Fig. 2, Plate XVIII.) In this case the shot-chamber might require to be rifled, and the superior diameter, *c d*, of the sabot would have to exceed slightly that of the front bearing device. The objection to this form of double chambering for lead-coated projectiles is that to be wholly efficient it must very slightly exceed the diameter of the bore, and, consequently, when it fouls, the shot would stick in loading. With the expansive projectile it would probably be kept comparatively clean by the sabot.

In all except his smaller calibres, Krupp makes the chamber eccentric with the bore, the axis of the chamber being above that of the bore. This is an attempt to have the projectile enter the bore as true as possible, by having their axes nearly coincident at the start. With the proposed projectiles this feature would not only be unnecessary but objectionable; and the chamber and bore should be concentric, for the reason that the projectile centres itself in the former before leaving it, and enters the bore a perfect fit and accurately centered.

The details of the proposed rifling for the double-bearing projectiles are given in the following table. *Without* the front bearing, the short chamber would be used, and the rifling, as has been stated, should be identical with that proposed for muzzle-loading guns:

TABLE X.

Details of proposed rifling for breech-loading guns.

Calibre of Gun.	Calibre of Chamber.	No. of Grooves.	Depth of Grooves.	Width of Grooves.	Width of Lands.	Length of Ramps.	PITCH.	
							Commencing.	Ending.
Inches.	Inches.		Inches.	Inches.	Inches.	Inches.	Calibres.	Calibres.
2.5	2.540	9	.040	.50266	.37	0.75	68	34
2.7	2.745	9	.045	.54248	.40	0.75	70	35
3.0	3.050	9	.050	.59720	.45	1.00	72	36
3.5	3.555	11	.055	.54960	.45	1.25	76	38
4.5	4.565	11	.065	.7352	.55	1.75	86	43
5.0	5.070	11	.070	.79800	.63	2.00	90	45
6.0	6.075	13	.075	.79997	.65	2.25	98	49
7.0	7.080	15	.080	.81608	.65	2.50	106	53
8.0	8.085	17	.085	.81840	.66	2.75	112	56
9.0	9.090	19	.090	.81812	.67	3.00	118	59
10.0	10.095	21	.095	.81809	.68	3.25	124	62
11.0	11.100	23	.100	.81242	.69	3.50	130	65
12.0	12.105	25	.105	.80799	.70	3.75	136	68
13.0	13.110	27	.110	.80267	.71	4.00	144	72
14.0	14.115	29	.115	.79663	.72	4.25	150	75
15.0	15.120	31	.120	.79013	.73	4.50	156	78

The pitch here given (the same as recommended for muzzle-loading guns) is admirably adapted to projectiles of the class shown on Plate XIX. It is, I think, almost equally well adapted to the double-bearing projectiles shown on other plates, as the constant difference in the angle of the pitch at the two bearing-points of the projectile, throughout its passage in the bore, would little more than make up for the "slip," and therefore the more positively assure the constant bearing of the soft front ring upon the lands.

*The advantages of the system.**—The advantages of this proposed system of projectiles and rifling for breech-loading guns will be apparent:

* Although the double-bearing projectiles, combined with the long or double chamber, and the projectile and short chamber shown on Plate XIX., might be called two distinct "systems," it is more convenient to consider them as simple varieties of the same general plan.

1. The action of the projectile having been explained, it is clear that in the case of the single-bearing projectile and short chamber (Fig. 2, Plate XIX.) there can be no undue strain from the checking of windage. The sabot is forced no more deeply into the grooves than occurs in a muzzle-loading gun, while the slight quantity of gas which escapes is distributed evenly about the projectile. In the case of the double-bearing projectile and long chamber (Fig. 1, Plate XIX.), the upper lip of the sabot being expanded, the first effect is to close windage, it is true, but not until the shot has got under motion; and although the sabot probably does not reach the rifled portion of the bore before the maximum pressure is attained, such pressure is at least confined to a shorter portion of the chamber; and the moment the rifling is reached, a moderate safety-valve is opened which will tend to prevent any accumulation of pressure in case of unexpected obstruction.

In the case of the lead-coated projectile, no matter whether the powder be quick or slow, the maximum pressure must invariably be exerted throughout the entire length of the chamber, for the windage is closed from the time the front portion of the projectile is forced into the rifling, and the pressure about the projectile is as great as in rear of it.

I may as well state, at this point, that if it is thought desirable, in the use of either of the expansive projectiles described, to entirely close the windage, this can be done very readily by a soft lead ring in front or by a thin flange on the base of the projectile; and, on the other hand, if windage is desired in the chamber as well as in the bore, it can easily be effected by grooving the sabot, by attaching it in segments, by grooving the chamber longitudinally with channels too narrow to admit of the sabot being forced into them, or by three or more holes running diagonally through the base of the projectile, and terminating at its cylindrical portion. But I consider the system better as it is.

2. The forcing of a lead-coated projectile into and through a gradually contracting bore of less diameter, or through contracting grooves, consumes, as has been explained, a great deal of power, develops, by the resistance, an increased powder-pressure behind the projectile, and imposes a wedging strain itself upon the gun. It needs no argument to show that much less strain must be imposed from these causes by projectiles such as are here presented. The forward part of the projectile, when a band is used, has little more bearing than is necessary to keep it centered and true, while the rear device, yielding to the compression as it is forced into the rifling, takes sufficient impression of the same to rotate the projectile, and is thereafter kept distended by the powder-gases during the passage of the projectile through the bore. After the first light compression by the

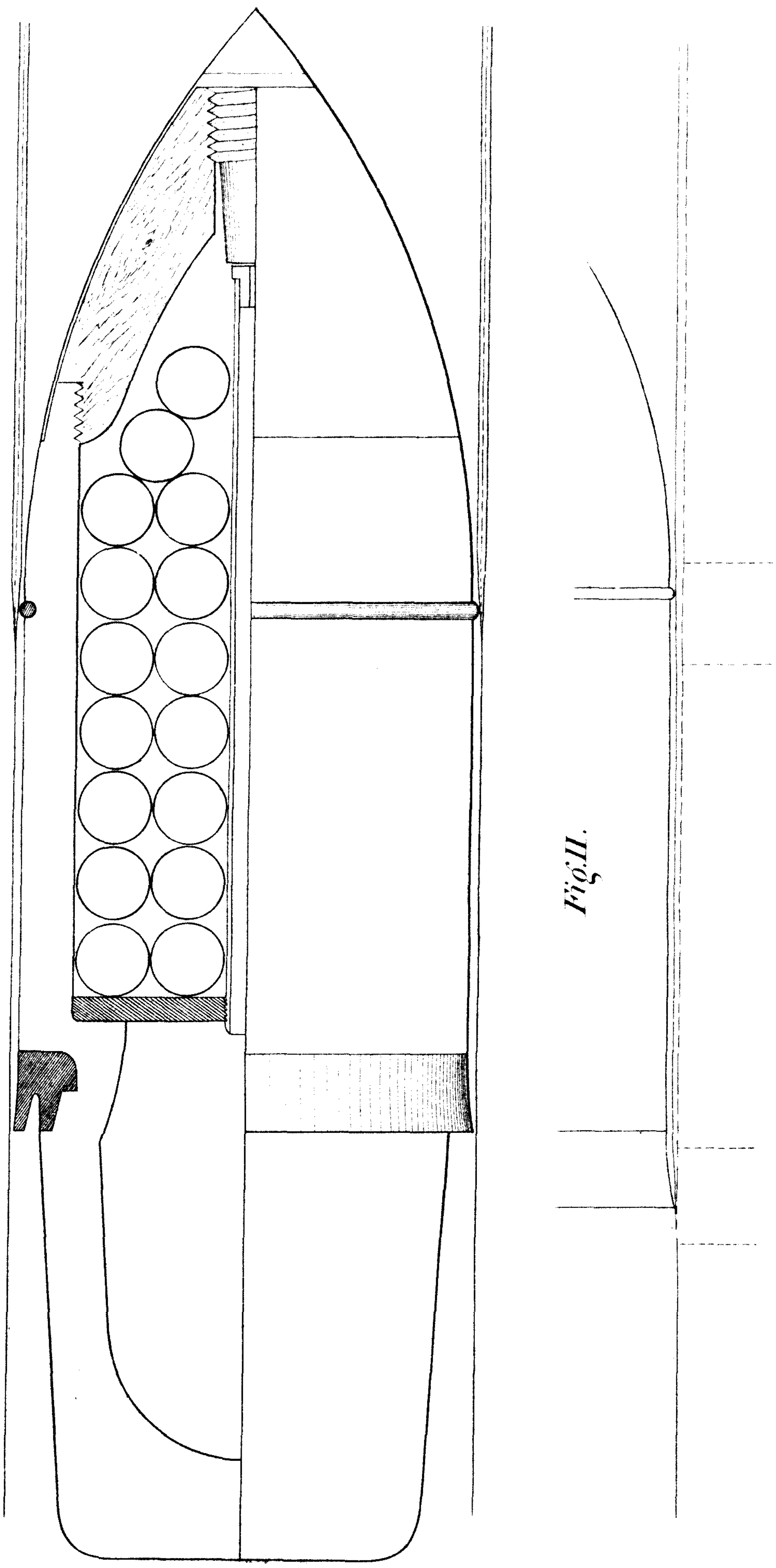

Fig. 11.

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rifling at the junction of the latter with the chamber, this shot produces no wedging strain whatever on the gun, but slides through the bore very much as a "steam-packing" piston moves through its polished cylinder.

3. Fouling must be less than with the lead-coated projectiles; and, therefore, any strains resulting therefrom must be proportionally reduced. "Leading" is, of course, impossible; and even if a front bearing of lead be employed, the expanded upper lip would probably remove all leaden deposits.

4. A bearing of lead upon iron is, mechanically speaking, one of the worst conceivable, and particularly under high pressures and velocities; on the other hand, a bearing of brass or copper upon iron is one of the most perfect.

5. The great reduction in velocity which the ordinary compressive projectiles suffer by forcing and fouling has already been alluded to. With the new projectiles, both forcing and fouling being lessened—the former, in fact, very greatly reduced—superior velocities must be attained. For the same charge and kind of powder, and the same weight and calibre of projectile, I see no reason why the velocity should not equal that of the muzzle-loading expansive projectile, in which case, other conditions being the same, they would surpass the lead-coated shot considerably in velocity, with assuredly less pressure. The friction of the expansive breech-loading projectile would exceed at first, at the point of its entrance into its rifling, that of the expansive muzzle-loading projectile; but this would probably be compensated for by a more thorough utilization of the powder-gases for the first few inches of the projectile's movement in the chamber, with possibly a slight increase of pressure.

6. The increasing pitch, although unquestionably more desirable in the breech-loading than in the muzzle-loading systems, on account of the projectile having considerable velocity when it suddenly "takes the grooves," is nevertheless impracticable with the lead-coated shot, as the changing angle of the pitch would shear the lead. But with the proposed projectiles the increasing pitch is entirely practicable, owing to the shortness of the bearing in the grooves by the upper lip of the sabot which conveys rotation to the projectile. The front bearings, when employed, having comparatively light contact with the lands, the varying angle of the rifling will be just sufficient to make up for the abrasion or "slip" of the bearings, and keep them in fresh and perfect contact with the lands throughout the passage of the projectile in the bore.

7. The proposed projectiles are not as liable to injury in store, handling, and transportation as those which are enveloped by a leaden jacket. If a severe dent in the brass sabot should, however, prevent the loading of the projectile, a few blows from a hammer upon the prominent parts would correct the matter.

The mere bending or mashing *in* of the upper lip of the sabot will not affect the satisfactory action of the projectile. This objection of liability to injury which is urged against the expansive, compressive, and stud projectiles by the advocates of mechanically-fitted, iron-grooved, or ribbed projectiles, has, in my judgment, but little force. The lead-coated shot is rather tender, it is true; but if this were its only fault, the objection could not be considered serious. I venture the opinion that the number of projectiles injured by dents and bruises resulting from handling is not large. Field-projectiles are packed in ammunition-chests, and suffer no very rough usage if packed properly. As to projectiles of larger calibre, there is no reason for handling them roughly, and they seldom receive such treatment. As to boxing them for transportation, if a projectile is worth anything, it is worth taking care of; the money value of its material alone would justify such care, to say nothing of the finished value or of any peculiar merit of the shot itself.

8. If the entire suppression of windage affects accuracy unfavorably, then on this ground we may expect the new projectile to prove more accurate than the old. There is reason, however, to expect superior accuracy on other grounds. In the first place, the proposed projectile being centered by the uniform expansion of its sabot in the chamber before entering the bore, it is believed that it will do so with its axis absolutely coincident therewith, while the lead-coated projectile is liable to enter the rifled portion of the gun with its base slightly depressed; and as the gases rushing over it have a tendency to keep it in that position while leaving the chamber, it cannot enter the bore perfectly true, nor receive rotation accurately about its longer axis. In the second place, friction being very much less, velocity will be greater, and the trajectory less curved, than with a lead-coated shot of equal weight, fired with the same charge. Again, it is unquestionably true that the smoother the exterior surface of a shot, other conditions being the same, the more accurate will be its flight. The lead-coated projectile, after leaving the bore, will be found very much roughened by the rifling. The proposed projectile, on the contrary, is, during flight, one of the smoothest in use, and is besides, for field service, a better shape, being longer. Holley says in reference to this subject: "The compressed lead-coated shot is also likely to be thrown out of line by the greater compression of the lead at one point than another." "The stripping of soft-coated projectiles with high charges is another source of inaccuracy." "The lateral motion of a rifle-shot, due to the resistance of the atmosphere, depends upon the smoothness of its surface. The projections formed on the shot to fit the rifling act like the floats of a paddle-wheel; and these must be most numerous and deep in a lead-coated shot, in case

of a high rotation, to prevent stripping; and these numerous ridges not only increase drift, but rapidly decrease the rate of rotation."

9. When it may be thought desirable to increase the charge beyond the usual capacity of the chamber, the proposed projectile affords a ready means of so doing by simply reducing or removing the forward bearing, or driving (that is, "forcing") the shot forward to the desired extent. In the case of large guns, where it may be thought desirable to have two charges for service—a light charge, for example, for ordinary service, as against light-armored or wooden vessels, earthworks, city bombardment, etc., etc., and a heavy or battering charge for use only against heavy iron-clads, strong fortifications, or for great ranges—two classes of projectiles may be employed, the heavy projectiles having the front bearing ring shifted back, so as to allow the projectile to be further advanced in the bore, thereby providing a greater space for the cartridge. On the contrary, the lead-coated projectile allows but a limited departure from a standard length of bearing, and to that extent will allow less variation of the charge. In the case of the short-chambered system, should occasion require it, the gun can be employed efficiently as a muzzle-loader, simply by keeping on hand some projectiles having the "*flare*" upon the sabot omitted. In this case any desired charge may be employed, and the gun loaded *either* at the breech or at the muzzle.

10. It is questionable if grape or canister can be employed in breech-loading guns, rifled and chambered in the usual manner, as the case of canister resting back of the rifling, and suddenly dashed into it, would in a very short time destroy the rifling in front of the charge, if not imperil the gun itself. On the contrary, the short-chambered system shown on Plate XIX. is admirably adapted to either grape or canister firing, since the case would rest entirely within the rifled part of the bore, held in position simply by a narrow flange at the bottom.

11. The long chamber for the accommodation of the lead-coated projectile must be as small in diameter as possible, as otherwise there is an objectionable amount of windage. If too small, it soon fouls, and the projectile "sticks" in loading; if too large, "scoring" or "guttering" is greatly increased, and even more serious difficulties are incurred. In the case of the shot-chamber here recommended, it may be any convenient diameter; neither the position of the shot nor the question of windage being in the slightest degree affected thereby. In the long or double chamber, when using the projectiles shown on Plates XV., XVI., etc., the expanded sabot will probably scrape off the foul deposit of each preceding discharge.

12. The chamber of a breech-loading gun, unless a cartridge-case be used, fouls very quickly, and is more difficult to clean than even the muzzle-loader, because the dirt is liable to get into the fermeture. The shorter the chamber, therefore, the more easily may it be cleaned; and the larger its diameter, the less frequently will it require cleaning.

13. The increased length of the rifled portion of the bore, in the case of the short chamber, and, in any event, the adoption of the "compromise" pitch for breech-loading guns, will, it is thought, prove of material advantage for reasons previously discussed.

14. Owing to the resistance which the lead-coated projectile opposes at the start—that is, its inertia, *plus* its resistance to forcing—the maximum pressure is developed very quickly, and increased; whereas, in the expansive breech-loading shot, this second source of resistance is comparatively trifling, and the projectile readily gets under way before the maximum pressure is attained.

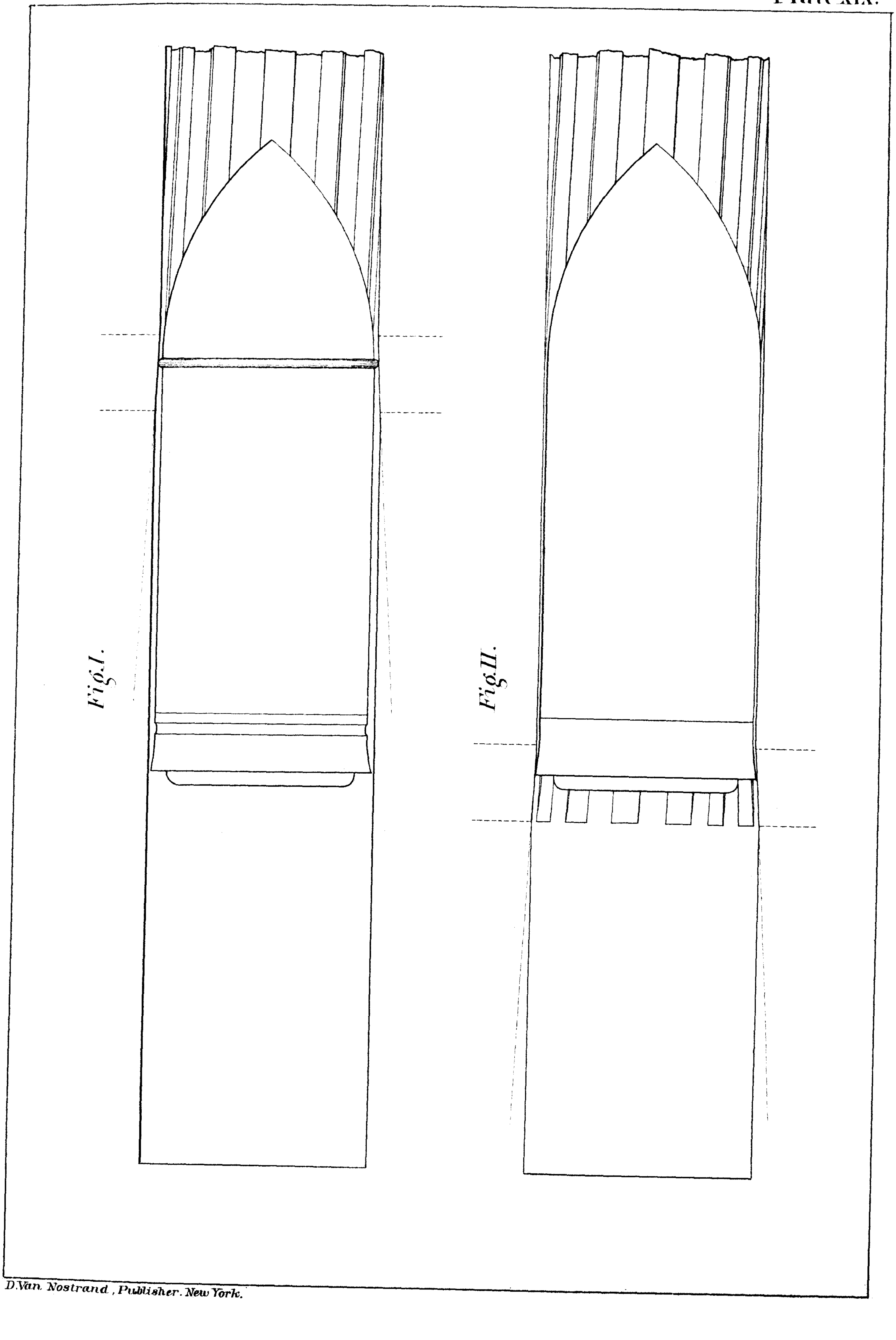
15. The proposed projectiles have a larger capacity for a bursting charge or as case-shot than the present breech-loading projectiles, the length of the lead-coating upon the latter being restricted by various circumstances.

16. Whatever the merit of the time-fuse, it is clear that it can be used in its simplest and best form in the proposed system of projectiles and rifling, as there is plenty of windage through which the flames of discharge may pass to the head of the projectile, which is not the case with the ordinary compressive shot.

17. The use of molten metal is entirely practicable in the new projectiles, and impracticable in any projectile having a leaden jacket. The shell being charged with the metal, I should simply adopt the precaution of attaching to the base of the projectile a light, sub-calibre wooden sabot to prevent contact of the cartridge with the base of projectile.

It is undeniable that the faults of the present systems of rifling and projectiles for breech-loading guns are many and grave, and any plan which gives fair promise of remedying these defects demands earnest consideration. How far the system herein advocated may prove a success cannot, of course, be absolutely known until practical trials have been made. It is submitted, however, with much confidence, that it will be found to possess, in a full measure, all the advantages of the old systems, with fewer and less serious defects.

Plate XIX.



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PART THIRD.

THE FLANGED SYSTEM.

The adoption, for our proposed experimental muzzle-loading guns, of the Woolwich or any other stud or flanged system of rifling and projectiles would, I think, be a mistake. I am aware of a prevailing dissatisfaction, in this country as well as in Europe, respecting the expansive system; but trust that, with the record of our recent experiments before it, the Board entrusted with the decision of this question may consider it unwise to abandon a system which, as recently improved, has shown itself equal to the severest demands of service, and seems to hold out such excellent promise of success. But, in view of a possible inclination to the contrary course, I am induced to enter somewhat more into detail in my discussion of the flanged system than I should otherwise consider necessary.

Under this system may be classed all those projectiles which have projections, in the form of studs, ribs, or flanges, on their surfaces, intended to be fed to the grooves in loading. And it may also be said to comprise all mechanically-fitted projectiles like the Whitworth and Lancaster; for the salient departures from a circle, in cross-section of the projectile, may be regarded as flanges, while the corresponding angles in cross-section of the bore, and into which these flanges are fed, constitute the grooves. It would pass the limits of this report to discuss these various modifications of a common system, none of which can be said to have given entire satisfaction, but all of which have revealed serious faults and shortcomings.

The English Government, during a series of costly and extensive experiments, extending over a period of many months, has passed through an experience with the expansive systems of Thomas, Britten, Jeffry, and others; with the compressive system of Armstrong, and various forms of lead-coated projectiles; with the "flanged" systems of Whitworth, Scott, Hadden, Lancaster, the Shunt, French, and others; and has at last adopted—or, as it may turn out,

"provisionally" adopted—a modification of the French rifling and stud projectile, known as the "Woolwich system."

It will be safe to assume that the English authorities at Woolwich found good and sufficient reasons for this decision in the revelation of grave defects in the numerous other systems so thoroughly tested; and, in deciding in favor of the Woolwich plan, were governed by a sincere desire to secure for their guns the most perfect system available. In fact, no other inference is admissible than that this system proved itself at least worthy of such preference. I shall, therefore, confine myself principally to a consideration of the Woolwich system of rifling and projectiles, simply premising that, whatever its defects, no other plan would seem up to this time to have shown itself so free from faults as to warrant its adoption in place of the Woolwich. (Such, at least, appears to be the view at the English War Office.) Therefore, in criticising the Woolwich system of rifling and projectiles, if we condemn it, we condemn *à fortiori*, from an English stand-point, the competing systems also.

It is unnecessary for me to refer in detail to the few experiments made in this country with flanged projectiles. The plane-grooved 8-inch and 12-inch shot, fed to the square grooves of their respective rifles, gave records which I presume have rendered the adoption of such a plan out of the question and criticism superfluous.

The Woolwich System.—This system is so well known as to render a description of it unnecessary. That the English have succeeded in building a strong gun is very generally admitted. Precisely the ratio in respect to strength between the Woolwich combination, Krupp's steel, and our best cast-iron guns has never been satisfactorily determined; although there is little question in my own mind that both the Woolwich and the Krupp rifles are unnecessarily strong (when perfect in material and construction) for the work actually accomplished by them. By strength I do not, of course, mean simply tenacity, but all those properties of tensile strength, compressibility, extensibility, hardness, degree and limit of elasticity, tenacity within elastic limits, uniformity of product, etc., etc., which could each be possessed in the required degree, and, united in one product, would render unnecessary all further search for a perfect gun-construction.

Whatever the merit of the Woolwich gun in point of strength, the results of practice are not considered satisfactory, while the gun itself yields nothing like a creditable endurance. If we admit the excellence of the material and gun-construction, and the good character of the English large-grained pebble and pellet powder, we know exactly where to attach the blame, and must necessarily lay it to

the projectiles and rifling. Briefly, I consider the rigid studs and rounded grooves, which constitute the French-Woolwich system, as one of the most ingenious plans for subjecting rifled guns to inordinate and destructive strains that could possibly be devised; and if, as we are to infer, it has impressed the British mind with its superiority over other competing systems, poor indeed must have been the performance of the latter. As to the Woolwich system being an "improvement" on the French, poor as the French plan may be, it seems incredible.

It is scarcely worth while to discuss in much detail the causes of failure in the Woolwich plan of rifling. It seems difficult indeed to believe that half-a-dozen shots could be fired without the wedging of a projectile by the "over-riding" of the studs on the rounded edges of the lands. Innumerable complaints from English sources that this is just what does occur, and occur frequently and destructively, give force to the belief that the Woolwich system is a failure.

Referring to Fig. I., Plate XX., which represents with sufficient exactness a portion of a Woolwich groove in perspective, and conceiving the bronze studs on the projectile which are intended to fit loosely into such grooves to be in place, it will be seen that the system has for its double purpose the rotation and centering of the projectile at one and the same time. The advocates of this plan for killing two birds with one stone have not, it is presumed, lost sight of the fact that the projectile is not "centered" by the curves cut out of the grooves in cross-section, but rather by the curves cut through the grooves by planes passing through the axis of the bore; and yet on no other hypothesis than the existence of such a misconception can the practice of rounding the edges of both grooves and lands be satisfactorily accounted for.* Thus, while a cross-section through the rifling shows in each groove a curved ramp, *a*, *b*, up which the studs are popularly said to climb in order to "centre" the projectile, longitudinal sections through the gun show in each groove a second ramp, *c*, *d*, *e*, of lesser grade, up which the studs actually do climb. It is just here that the mischief occurs; this second ramp is so gradual in ascent, especially with the increasing pitch, as frequently to lead to the wedging and jamming of the projectile, the over-riding of lands, etc., etc.

The English are very severe critics of their own system, and the complaints respecting it are so universal that I question if the system will be retained much longer, at least without further modification. The *Mechanics' Magazine* says in this connection:

* True, if the bearing-edges of the grooves be square, and the Woolwich stud has free play therein, the shot will "dance about" or ballot within the bore in rather an objectionable manner.

"The naval and military journals are beginning to complain that six years of ceaseless improvement have failed to provide our heavy guns with suitable projectiles. The unexplained and extraordinary pressure of sixty-six tons to the square inch in the powder-chamber of the thirty-five ton gun, instead of the usual thirty tons due to the charge, and the consequent splitting of the steel lining, have given point to these complaints.

"It has been suggested that, as the soft studs of the shot are frequently wrenched out of their sockets, or squeezed out of the grooves and over the lands, this may have occurred to the thirty-five ton gun, resulting in a check to the exit of the shot, and consequent increase of pressure in the breech.

"The cause of this wrenching out of the sockets, or flattening of the studs, which often results in the breaking up of the projectile, is not far to seek. Our readers will remember that the gun has nine grooves cut into the lining, and that the projectile has two soft-metal studs for each groove, equidistant from the centre of gravity and about eight inches apart, on which it is poised, and by which the rotary motion is secured. These studs are set up into undercut holes 1.6 inch in diameter and 0.3 inch deep, forming two rings, which so weaken the walls of the shell that we are authoritatively told that a cracked projectile may be divided in two with surprising ease by a blow on the stud, as fixed on the present system. One ring of studs, denominated the 'driving studs,' concentrates the whole effort of rotation upon itself, bringing the entire strain on about half an inch of the groove at a time and as a constant on the same position of the projectile.

"The squeeze is enormous, and all efforts during six years to enable the stud and the projectile to withstand it have resulted in the reduction of the capacity of the shell in the larger calibres, without attaining the desired end.

"Bearing in mind the enormous expenditure upon the Armstrong lead-coated projectile, before that could be superseded, and what has already been incurred upon the studded one, it would seem to be high time that the further manufacture of these projectiles should cease until all their defects have been overcome, or until the description of shot that is to supersede them is settled."

"The *Engineer*," says the *Army and Navy Journal*, "directs attention to what we may call the mechanical cruelty of 'seizing a shot and forcing it to rotate through the medium of its studs. Chilled projectiles generally cracked themselves in a line running through the studs. In some cases it was found very difficult to break cracked shot or shell into two parts, until the expedient of striking a blow on the stud was resorted to, when the projectiles at once opened

Fig. I.

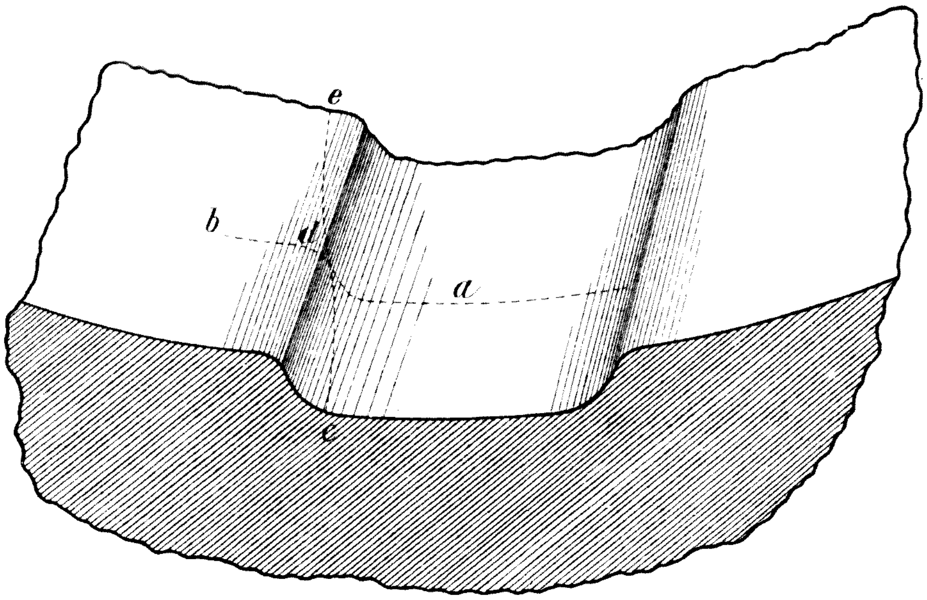
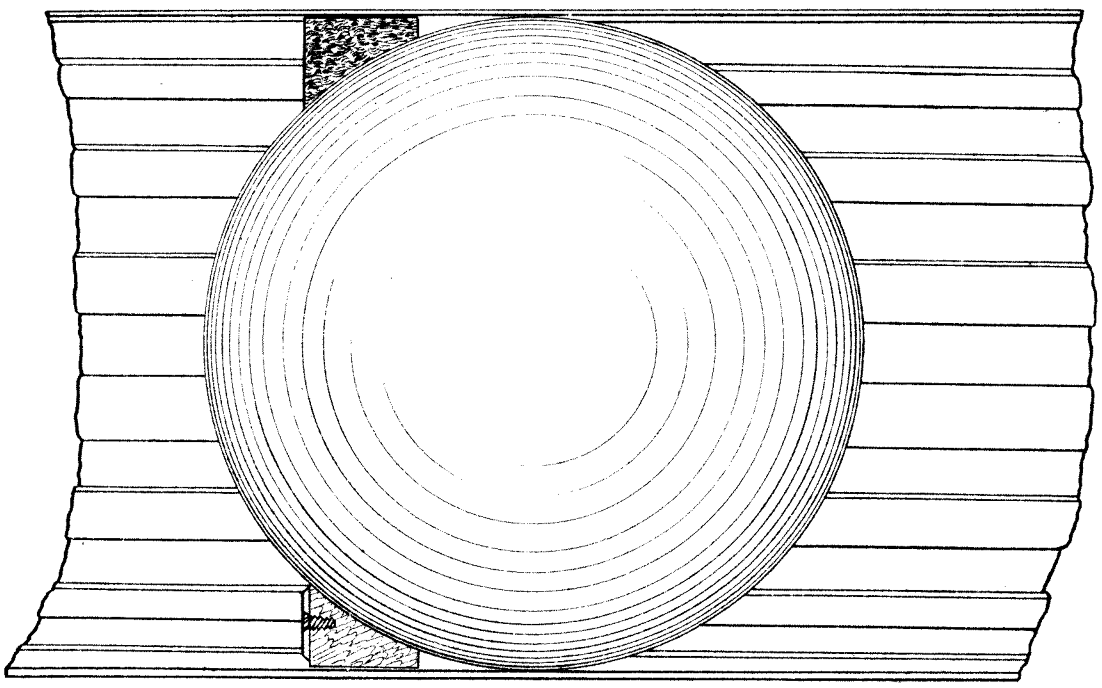


Fig. II.



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asunder.' This explains why studded projectiles always break up through the stud-holes opposite to the grooves or weakest part of the gun."

Commander Dawson, R.N., in an interesting paper read before the United Service Institution, severely criticises the Woolwich system of rifling, and attributes to it "the short lives of the present English guns." He also finds fault with the increasing pitch, and condemns it as especially hurtful in the studded systems. From this paper I will make a few extracts:

"The ablest artillery authorities are agreed that a new system of rifling must be sought for the heavier guns, if they are to throw shells of adequate length, and to endure rapid continuous fire, such as they will be subject to in well-contested naval actions or in bombardments. It behooves artillerists, then, to study the mechanical principles which distinguish the few systems of rifling which have been successfully tested, with a view to observing their relative merits, and to forming intelligent opinions on such schemes as may be presented for adoption. Now, seamen have great opportunities of close observation, and, if they will only collect and collate numerous facts, may add greatly to the stores of knowledge, and they may enable artillerists to deduce from those facts some of the true principles of science. After the expenditure of two and a half millions sterling in five years, the Duke of Somerset confessed, in 1863, that the country had no better gun than the 68-pounder; and although the Armstrong projectiles had been tried, there was no prospect of supplying our iron-clads with heavy rifled guns, and, in despair, the Admiralty insisted upon having various heavy smooth bores.

"Again, the object of rifling a gun at all is to spin the projectile so perfectly that it shall 'sleep' like a boy's peg-top when well spun, and not wobble like the same top when badly spun. A well-spun shot flies through the air point foremost, making a sharp 'whizzing' sound, such as every rifleman is familiar with. A sharp 'whiz' indicates that the bullet has been centered in the bore, and that the rifling has done its work well. But an intermittent 'puffing' noise in the air indicates eccentric gyrations, which have been impressed upon the projectile whilst still in the gun. A 'puffer' in the air is necessarily a 'wobbler' in the bore; and, though the 'puffer' reaches its destination in due time, its range is decreased by the expenditure of effort in 'dancing' instead of walking the distance.

"As the Woolwich projectile sits in its seat in front of the powder charge, it rests upon the two lower studs, no other part of the shot touching the bore. The centre of the shot is, therefore, below the centre of the bore, and there is a considerable space above the shot, the loading side of the two lower studs

touching that side of the lower groove. When the charge is ignited, a horizontal blow is inflicted on the base of the shot above its centre, and the gases escaping above it strike also a downward blow in the rear. The shot, being balanced on two studs, has its rear struck downwards and its front tipped upwards by the escaping gases. This originates a vertical hammering action, which shows itself sometimes by flattening the lower rear stud, by spiking the lower groove about twelve inches forward of the seat of the rear stud, by spiking the upper groove about twelve inches forward of the spot over the seat of the fore stud, by scoring the base of the shot, or by flattening in certain cases the seat of the shot. Moreover, the lower studs resting at the bottom of a curved groove necessarily come into bearing on the driving side before the other studs, which have a less deep hold of the other grooves. Each set of studs comes thus into driving bearing successively, imparting a succession of blows which result in a lateral wriggling motion. Should the lower rear stud have been flattened by the vertical blow of the escaping gases, it will come into driving bearing at a still earlier period than its fellows. As the projectile proceeds along the bore, another set of studs occupies the lower position; and as these have not suffered either from the vertical blow of the escaping gases or from the side blow of first coming into bearing, their force is unaltered, and they take the grooving at a less depth, again altering all the bearings of the several stud rows.

"We have thus a succession of lateral wriggling motions imparted to the projectile as it turns round in its passage along the bore. When an increasing spiral is superadded to the difficulties placed in the way of the shot's escape, it is evident that the muzzle strains must be greatly enhanced, and that the major part of the work of rotation must be borne by the one rear stud in the lower groove. Indeed, it has been found that, by cutting away the front studs and several of the rear ones, the wriggling is not so very much worse than when they are all present, showing that the work of rotation is really shared by very few of the studs. As the centre of the French shell does not rise to the centre of the piece, the principal powder-action on its rear is above the centre all along the bore in its exit. So that we have in the non-centering Woolwich stud system a maximum of lateral wriggling and vertical hammering, and a minimum of rotary power. The natural result is that the projectiles are imperfectly spun, and the sure index that it is so is the 'puffing' noise with which every naval officer is familiar."

From an article, entitled "Wobbling of Woolwich Shell," in a recent number of the *Mechanics' Magazine*, I extract as follows:

"The object of rifling in an elongated projectile is to compel it to spin rapidly

round its major axis. To do this effectively the centre of the projectile must coincide with the centre of the bore, and it must be so gripped longitudinally that it cannot oscillate vertically or horizontally. About the most unmechanical contrivance known to us for achieving this purpose, is the French system of studded rifling, at present in use in the British service, by which the projectile is balanced on two points in the lower section of the bore. According to all mechanical principles recognized among engineers, this plan seems clearly devised so as not to centre the projectile in the bore, and not to spin it perfectly round its major axis. It would, indeed, puzzle a mechanician to devise a more fallacious system of rifling, if mechanical principles have any truth in them. Yet the '*Pall Mall Gazette*,' among other very confident assertions, states that 'it is not a fact that our projectiles "wobble."'

"Now, either all recognized mechanical principles are false, or the '*Pall Mall Gazette*' is as mistaken in this apparently inspired assertion, as in the many other self-complacent assertions and point-blank denials which it makes relative to the effects of French rifling in British guns. This is a plain question of fact, 'Do our projectiles wobble,' as pointed out by us, and as they ought to do according to the laws of mechanics, or do they spin truly and sufficiently round their major axis? If they do not spin, the whole object of rifling the gun is defeated; but if they do spin truly and sufficiently, then a new principle in mechanics has been practically established.

"We have before us certain official works, published by the Secretary of State for War, and issued by the Department of the Director-General of Artillery, neither of which officials would desire to say one word deprecatory of the present service system of rifling; and we have also the Professor of Artillery's work on modern artillery. The latter tells us:—'In hard projectiles, having studs, there will generally be a slightly oblique movement of the axis of the projectile—in other words, "wobbling."'

"The official work 'On Ammunition,' Part II., page 58, states that 'the Committee on Field Ordnance for India report that recovered projectiles fired from an experimental "Woolwich" gun showed clear evidence of non-centering.' The Ordnance Select Committee reported, 4th August, 1865, that the 7-inch double 'shell roll considerably'; and the captain of the *Warrior* reported, 25th January, 1870: 'I may mention that three out of seven double shell, on being fired, appeared to turn over and over before reaching the target.' In February, 1868, the 12-inch common shell, 600 pounds in weight, 36.15 inches long, and containing 45½ pounds bursting charge, were being fired from a 25-ton gun, when 'the practice with the common shell was stopped on account of the shells appear-

ing to turn over in flight. All had two studs in each groove, 18 in all; but they were . . . only six inches apart.' In April, the 'Committee prefer to try the effect of reducing the weight of the projectile.'

"Accordingly, the studs being incapable of giving sufficient rotation to the 12-inch common shell, as 'these proved, on trial, so exceedingly unsteady in flight, and that so indifferently,' they were reduced from 600 pounds weight to 495 pounds, and their bursting charge from 45½ pounds to 35 pounds. Practice was resumed with these reduced shell (as now adopted), and on 15th October, 1868, we read of them—'Ten shells have been recovered. In several, the rear studs have been slightly moved forward by the explosion of the charge, and all are scored on the base (for about one-fifth of the circumference) by the grooving of the gun; the length of the scoring averages about three inches.' If the studs had worked truly, the body of the shell could not have touched the bore at all; the scoring of the base shows that the shell 'wobbled' in and hammered the gun.

"On 4th May, 1870, the Director-General of Naval Ordnance asked:—'Do you consider that the increase of the twist given to this (35-ton) gun will entirely obviate the inaccuracy of flight now observed in the 12-inch gun of 25 tons at very short ranges?' To which the Superintendent Royal Gun Factories replied: 'No, I should not think it would altogether.' 'Should you be afraid if you adopted a sharper twist, say 1 in 25, that the studs would be sheared?' 'I should be afraid so, or I would have adopted it. The stud in the projectile confines us to giving a less twist than I should like to give to any gun.' Again it is reported, 'The same difficulty has been experienced with the common shell for the 11-inch gun' of 25 tons, which were 530 pounds weight, and contained 40 pounds bursters. 'The practice with common shell (and 54 or 65 pounds pellet powder charges) was discontinued on account of the unsteadiness in flight, by order of the Ordnance Select Committee, who were present, 22d September, 1868. Two rounds were fired with 65-pounds charge, to ascertain what effect the increased charge had on the shooting; the inaccuracy of the shells was, however, greater than before.' Accordingly, no less than 128 pounds in weight and 15.8 pounds bursting charge was taken away from the 11-inch common shell; yet we read in the official reports, July, 1871, of these stunted shell, that of 30 fired, 4 were 'unsteady,' or 'noisy,' both terms referring to the same 'wobbling' motion in the air. And in August, 1871, we read: 'The common shell which have been supplied have proved too weak, and a stronger pattern has been demanded.'

"This 'wobbling' in the gun brings great strain upon the studs, and causes the shell to break up through the stud-holes and opposite to the grooves, which

are the weakest part of the gun. Thus, we read of the 11-inch Palliser shell, 'The broken shell have been recovered, and out of the eight fired, only two are undamaged. The condition of the rest is as follows: one with head broken into three pieces and off at front row of studs, and broke up in the gun; one with head broken off entire at position of studs, etc., etc., and broke up in the gun; four with the heads broken off entire at the front row of studs—two of these broke at first graze and two at last graze.'

"In May, 1871, five common 10-inch shells, recovered at Shoeburyness, were found 'slightly set up and scored in some places by the edges of the grooves, and in others ground down by the lands of the gun,' showing that the studs had been hammered flat by the gas escaped over the shot. The walls of the 10-inch shell had also to be thickened from 1.65 to 1.85 inches, the powder capacity being reduced from 32 pounds to 26¼ pounds. And after this we read that so recently as July, 1871, an experiment 'was carried out at Shoeburyness to ascertain the cause of the premature explosion of shrapnel and common shells.' Of six common 10-inch shells recovered, there was 'one marked on base by three of the grooves in the gun'; and of fourteen 9-inch common shells picked up, there were 'three marked by the grooves of the guns, and two marked on bases by grooves of gun,' showing that, up to the last published official record, the bores of guns are being hammered by their shells as they wobble their devious way out of the guns. We have given the official words of a few of the published returns, to show that the statements of naval gunners, as to what they see with their eyes and hear with their ears, are not mere 'fancy.'

"We have traced this matter, in official language, to show how mendacious is the assertion of the *Pall Mall Gazette* that 'it is not a fact that our projectiles wobble.' Space will not permit us to deal with the other point-blank denials unblushingly made as to naval 'fancies,' for we do not wish to meet assertion by assertion, but by official facts, of which we have a large store at hand, to prove the scrupulous accuracy of the table of injured guns given originally in the *Naval and Military Gazette.*

"The *Pall Mall Gazette* has taken that table to pieces; but it has only been able to point out a single error, and that not a very important one, namely, that a certain gun which flew into 76 pieces, scattered over an area of 580 by 150 yards, at the first round on the 10th of August, 1870, had previously fired 164 rounds on former occasions. This frightful explosion, as well as a similar one of a 12½-ton gun on the 25th of September, 1868, were, in our opinion, exclusively due to the 'wobbling' of the projectiles in the bore, and to the consequent obstruction to their escape."

From the same paper I quote the following:

"We have urged elsewhere the extreme desirability—the necessity even—of these guns being subjected to a satisfactory and conclusive test of their endurance, by continuous fire, such as would inevitably be required of them in the event of war and a hostile collision with an enemy. We regret to learn that, although this question has been urgently pressed upon the consideration of the authorities, yet their decision has been to the effect that the 25 and 35-ton guns shall not be exposed to such a test.

"Nothing could by any possibility supply stronger evidence of the doubts which rest upon the powers of endurance of the guns, even in the minds of the Woolwich authorities; and no confirmation could possibly be stronger of the truth of the allegations made against the guns—namely, that, big and massive as they are, their strength is yet insufficient to withstand the extraordinary and irregular strains to which they are exposed, and which are entirely due to the system of rifling adopted."

The *Broad Arrow* says:

"*Engineering*, as well as the *Mechanics' Magazine*, concur with the other mechanical journals, the *Naval and Military Gazette* and the *Standard*, and the leading papers of our great naval ports, in denouncing the present gun system, which, as they point out, is so faulty that the *Hercules*, which alone has had any lengthened experience with its application in the 18-ton guns, cannot get through 'the ordinary quarterly training practice at targets without disabling three out of her eight 18-ton guns in less than three years.' Well may naval commanders feel alarmed at the prospect of being knocked over by the broken pieces of the shell of a *friendly* vessel; and well may the captains of our turret-ships hesitate at firing over or near bulk-heads, which a split projectile might unhappily pass through, to the great destruction of life. We are still at peace, and we trust that the favorable opportunity for reviewing the condition of our guns, as well as improving our powder and keeping it dry for any emergency, may not be lost."

A recent number of *Engineering*, in an article entitled "French Rifling in British Guns," says:

"Seven years ago the French soft-metal stud and bearing was adopted, under the name of the 'Woolwich' system for rifling British muzzle-loading guns. At that time very little experience was extant as to rifled muzzle-loading heavy ordnance. If there were any such guns issued to the navy, they were rifled upon a plan known as the 'shunt,' now universally condemned as most unmechanical, and therefore totally abandoned. Military men had, in 1865, little more experience of rifled muzzle-loading heavy ordnance than naval gun-

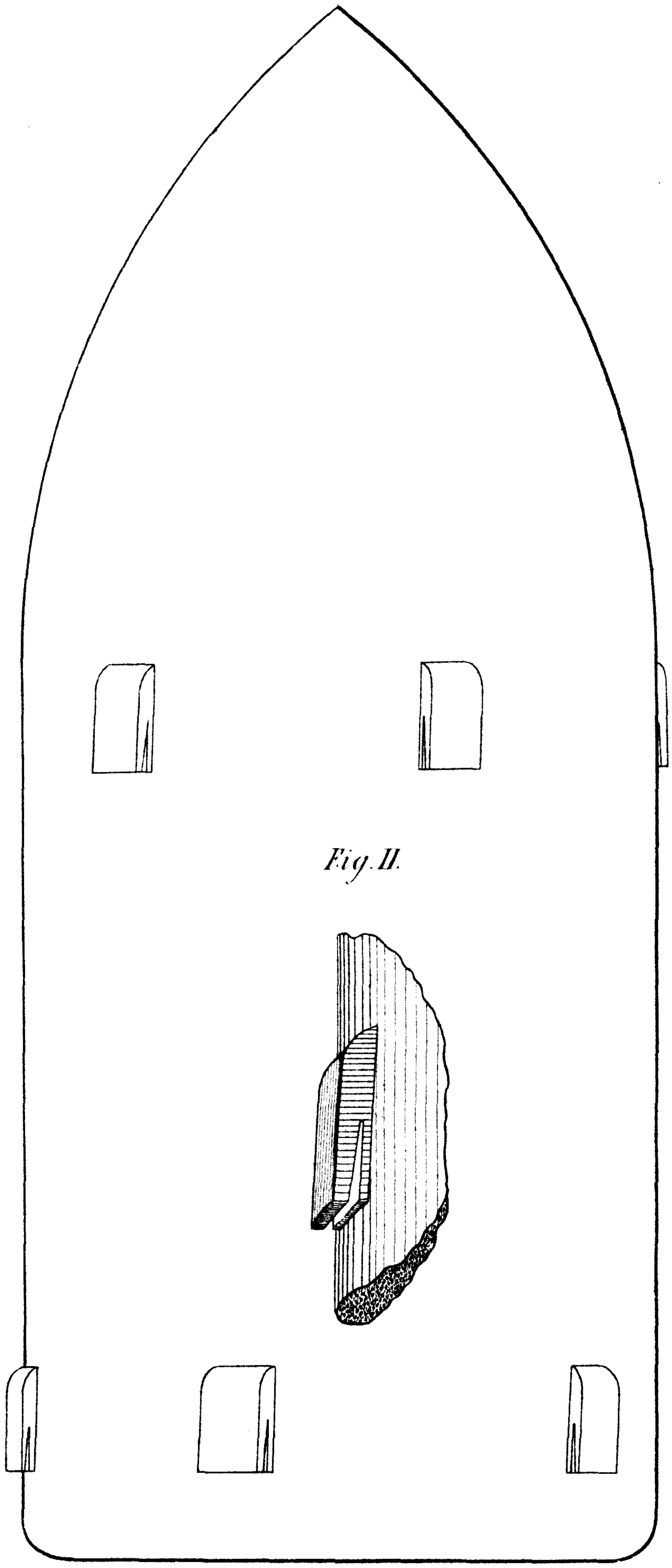

Fig. II.

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ners. True, a few able and distinguished officers doing duty at Shoeburyness and at Woolwich had had considerable experience of the many experimental systems of Sir William Armstrong, every one of which was conceived on such unmechanical principles as necessitated their subsequent abandonment. But so little were the true mechanical principles of rifling then understood, that we find six able officers of both services eulogizing the now abandoned 'shunt' system, in a report dated May 1, 1865, in these words: 'If the so-called French system should fail in larger calibres' than 9-inch, 'the natural course would be to fall back upon Sir William Armstrong's, which holds the second place; which has been more thoroughly studied and worked out than any other, and through a wider range of calibres; which is actually in the service in the muzzle-loading 64-pounder guns, and to which so many of our existing experimental guns of large calibre, the 600-pounder, 300-pounder, 9.22-inch, or 220-pounder, are conformed. To throw away the experience gained with these guns, and the expense incurred in the preparation of patterns and means of manufacture, without good cause, would be to postpone, unnecessarily, the great desideratum of a settled system, and plunge anew into tedious and costly experiments, on a mere hypothesis of improvement.' Compare this prophetic eulogium with the subsequent fact that the 'shunt' system altogether failed 'in larger calibres' than 9-inch, and that after five years' further 'tedious and costly experiments' upon the studs of its smaller projectiles, it was finally abandoned, in 1870, for even small calibres.

"It is no disrespect to the intelligence of the gallant and able officers who recommended for adoption not only the original breech-loading lead-coated system, but each of the manifold lead-coated varieties which succeeded it; or who eulogized the 'shunt' system in each and all of its phases; or who, in 1865, discovered an unexplained 'disposition to admit of the advantage of an increasing over an uniform spiral,' and who, accordingly, 'determined to record their unanimous opinion in favor of the so-called French system,' to assert that the expenditure of four or five millions sterling has taught every intelligent officer and instructor of the Royal Artillery and of the Navy, far more of the mechanical principles of rifling than was known by any half-dozen of their number at the dates referred to.

"Seven years' large experience of the French system has led able and intelligent artillerists to collate a large number of observed facts, and to apply to those facts simply mechanical laws. By clearing away the mystic smoke of gunpowder and the cloud of partisanship which obscures scientific investigations, it is found that the violation of certain simple mechanical principles ex-

plains almost every mark observed on recovered shell, and every injury inflicted by the escaping projectiles upon the lands and grooves of their guns.

"Ignoring these simple mechanical principles, and declining a patient investigation into the causes of the marks and injuries referred to, excuses are resorted to by partisans committed to the French system to explain away, instead of carefully examining, established facts. By this means alleged causes of damage may be removed further off, but they still remain, in their new position, a matter for further explanation.

"We can well understand that the recent revelations as to the performances of our heavy guns are not very agreeable to the gentlemen who originally recommended the French system of rifling for adoption, nor to those gentlemen who have been inventing theoretical hypotheses to explain its wonderful agreement with the laws of nature. But if these gentlemen would convince others of the soundness of their views, they must set about, not explaining away, but preventing these ugly facts. We have no doubt that they will fight hard for their 'particular baby.' All we ask of them is to condescend to the infirmities of ordinary minds, and to explain the remote as well as the near causes of the various marks found on recovered projectiles and in the interior of many guns. The principles involved are those of the merest elementary mechanics. Let these be carefully, and honestly, and truthfully applied, and we have little doubt that the non-centering properties of the stud system will be patent to all intelligent minds."

From an interesting article called "Powder-Pressures," in the *Mechanics' Magazine*, I extract as follows:

"The admirable system of registering the maximum pressures exerted by the gases of exploded gunpowder in the chambers and bores of heavy guns, and upon the bases of large projectiles now in use at Woolwich, is a great improvement on that originated by General Rodman in America.* The pressures are measured by the compression of prepared copper pellets, which are enclosed in cylinders provided with suitable pistons, holes being bored through the walls of the gun to receive the apparatus. There seems no reason to doubt the uniformity of action of the crushers.

* It is difficult to understand how our English friends can believe that the substitution of a column of metal to be crushed, for the knife and disc, constitutes an improvement of the Rodman apparatus, which is obviously the more sensitive of the two instruments. I believe that in the English experiments the "crusher gauge" was placed next to the powder, and a Rodman external gauge applied outside the gun; an obviously unfair comparison. One of our several forms of *internal* gauges should have been employed.

"Having tabulated the various powder-pressures, a question arises as to the use to be made of the information thus obtained. And on this head some very wild crotchets have been started. But before we are in a position to make any practical use of the tables, they must be carefully sifted by the application of one or two very commonplace but much-forgotten principles. For example, it is very obvious that the pressure registered with a given charge must, among other things, depend upon the ease with which the shot escapes out of the gun.

"If we imagine an elongated projectile to fit the bore mechanically, so as to traverse it truly in the centre, and, as it were, upon rails, without the possibility of a wriggle, then the pressure registered would be at its minimum; but if we suppose the elongated projectile to lie in the bottom of the bore, with its centre below the centre of the piece, with all the windage above it, and balanced upon two points nearly under its centre of gravity, so as to ensure the maximum of wriggling, the powder-pressure registered will be largely influenced by the extent and position of the wriggle in the bore. Should the non-centering balanced shot happen to escape without a wriggle, the powder-pressure will be small; but should the principal wriggle take place near the muzzle, the pressure there will be greater; and should it take place near the powder-chamber, the gauges will there give the largest register.

"When the *Glatton* fired her 25-ton guns fore and aft at Sheerness, the non-centering balanced projectiles happened to escape easily, and many of the powder-pellets were thrown out of the gun unconsumed, cutting up the decks considerably. But had the shot wriggled, more of the powder would have been burnt, and the recorded pressure would have been greater.

"To avert a portion of this wriggle the common shell of the 12-inch 25-ton gun has had 6.15 inches taken off its length, 105 pounds off its weight, and 10½ pounds out of its bursting charge. Yet, notwithstanding this enormous reduction of effective work, it is still found that the projectiles wobble in the air, and are inaccurate at short ranges, so that we may still look for variations of powder-pressures due to this cause.

"Need we say that the increase of pressure due to wriggling arises from the detention of the powder in the gun, and consequently to its greater consumption? That this action is very considerable is evidenced by the marks found on the gun-metal studs of recovered projectiles. Mr. Lancaster recently exhibited seven studs on which some non-centering 700-pound projectiles had been balanced in the 35-ton gun, when tried at Woolwich. Several of these studs were squeezed out of all shape, and were simply blotches of gun-metal,

showing that they had over-ridden the grooves at least 1.45 inches, *i.e.*, their own diameter—a monstrous wriggle for such a projectile. Some other of Mr. Lancaster's specimen Woolwich studs had the whole of their exposed surface or head broken off, showing that the wriggle may have had no limit whatever. These wriggles represent little jams of the projectile in the gun, delay in escape, extra consumption of powder, and consequent increased powder-pressure.

"Until we can eliminate this uncertain yet large source of error, it would be most unsafe to build up any theories on the action of crusher-gauges and of various gunpowders, inasmuch as the pressures registered may only be measures of the eccentric action of non-centering projectiles balanced on two points. To get regular readings from the gauges we must employ a system of rifling which, by centering the projectile in the bore, and affording long bearings with a mechanical fit, allows the shot to escape with a uniform action and without a wriggle.

"Again, everybody knows that, throughout a series of continued discharges on the same day, the guns recoil more and more violently. This arises from the temperature in the gun being so raised as to cause an extra and more expeditious consumption of powder. The increased violence of recoil implies also a greater blow on the base of the projectile. Now, if the system of rifling promotes wriggling when the gun is cool, it will do so far more effectually when it is hot, and this extra and more rapid consumption of powder causes a more violent action upon the projectile.

"For example, many of the pellets thrown out of the *Glatton's* 25-ton guns at Sheerness would, had the guns been heated, have been consumed, and it is a question whether the shot would have escaped from their violence at all. Now, if we apply these two simple and obvious principles to the pressure registered in the 35-ton gun—and, remembering Mr. Lancaster's specimen studs, we may truly do so—we have a sufficient explanation of the phenomena, without resorting to any arbitrary hypothesis of gas-waves, or of gunpowder developing some new properties when exploded in quantities exceeding 100 pounds. The maximum powder-pressures registered at the axis of the piece, at the vent and at the base of the projectile, with the heavier charges, varied arbitrarily and irregularly, and the muzzle velocities were found to bear no relation whatever to the action of the charge upon the bases of the projectiles. Thus, while one 700-pound projectile was struck by a 120-pound charge with a blow of 46.8 tons, and another with a blow of 39.6 tons, the muzzle velocity was exactly the same in both cases, showing that the one had wriggled more than the other. Again, a third 700-pound projectile, struck with a force of 45.4 tons, actually gave a velocity six

feet greater than the fourth one, which received a blow of 53.2 tons. These conflicting results from four consecutive 120-pound charges of pebble powder, fired behind 700-pound projectiles in the 35-ton gun, are worthy of study, and we accordingly append them :

Velocity.	Total Work.	Maximum Powder-Pressures at		
		Axis of Gun.	Vent.	Base of Projectile.
1,366 feet.	9,059 foot-tons.	46.8 tons.	35.2 tons.	45.4 tons.
1,360 "	8,973 "	66.0 "	42.6 "	53.2 "
1,334 "	8,639 "	44.6 "	34.2 "	46.8 "
1,334 "	8,639 "	37.6 "	27.0 "	39.6 "

" To seek to establish any true principles of artillery upon powder-pressures so obtained would be utterly fallacious. We must eliminate the wriggling action of the projectile by a system of rifling, which will, by a suitable mechanical fit, centre the projectile in the bore and secure the maximum extent of bearing surface. We must then carefully compare the first rounds on each day together, and the latter rounds together, or ascertain and allow for differences of temperature in the powder-chamber. This latter source of error is a very serious one, so serious that the authorities have not yet ventured to subject the 25-ton or 35-ton guns to numerous continuous discharges on the same day, such as would arise in an ordinary naval engagement, lest the extra consumption of powder should lead to the destruction of the guns.

" Would it not, however, be better to discover the lack of endurance of the guns for which our *Glattons* and *Devastations* are built, before those ships are called upon to take part in a well-contested naval action ? It would, indeed, be a disastrous result, if, in the heat of a hostile encounter, our most powerful iron-clads were disarmed by the action of their own wriggling projectiles wobbling their way out of the guns. Better by far try the experiment upon one gun of each of those calibres now, in time of peace, when the discovery would be of comparatively little consequence, and the certainty obtained would be invaluable.

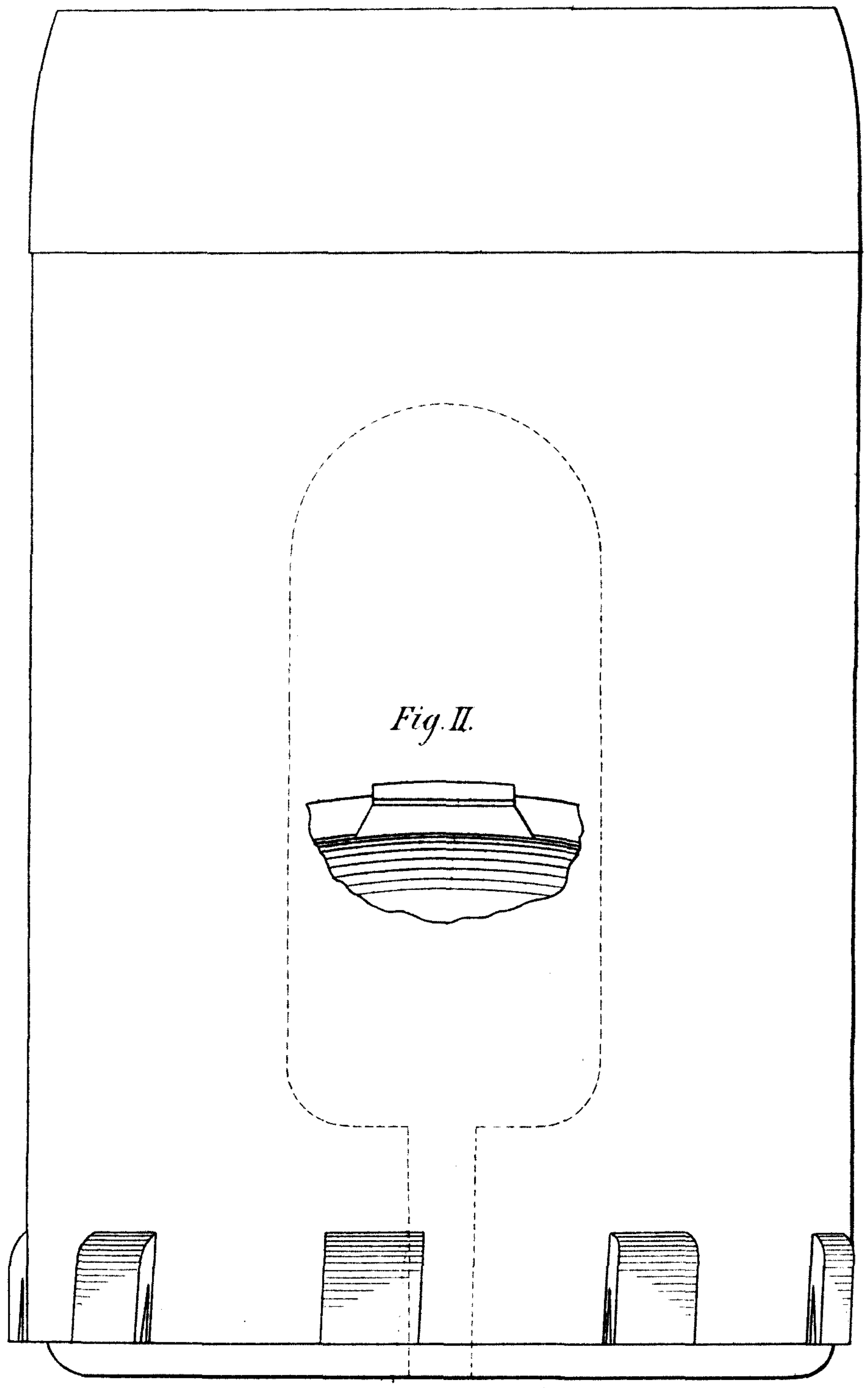
" The Navy is alarmed at the mishaps which have already occurred in firing a few rounds occasionally at canvas targets, and asks, not unreasonably, what may be expected when guns so rifled are subjected to rapid continuous fire in a bombardment or naval action ? True, it is, indeed, considered no small merit in ' Woolwich ' rifled guns that a sea voyage in time of peace has not led to their

bursting their sides and destroying their crews. If this be a merit in a naval gun, it is one that seamen should be thankful for. But we fail to see why sea air should in itself be regarded as hurtful to heavy artillery. It is the rapid, continuous fire which is the true test of endurance. This has heretofore always been applied before a new gun was adopted for the Navy; but this obvious test has not been applied to either the 25-ton or 35-ton guns; and there are grave reasons to doubt whether their non-centering projectiles balanced on two studs could escape from the bore when ejected with such extra violence. Coil guns, wrongly rifled, have repeatedly burst explosively like other guns, and may do so again if we do not gather wisdom from the obvious teachings of the registered powder-pressures."

In the foregoing extracts from the English records may be observed the same anomalies which have been previously shown to have obtained in our expansive system (see Table I.) It will be noticed in the English experiments, that in the second round the pressure is greater by over 43,000 lbs. per square inch at the axis of the bore than in the first round, *with absolutely less velocity;* and that in the last two rounds the velocities are identical, while the pressures vary by over 15,000 lbs. per square inch. Even this latter variation in pressure should never obtain with powder of fair quality, if the projectiles are good.

From the same source I quote again:

"As Sir William Armstrong certifies that 'the maximum pressure' (in the powder-chamber) 'causes the failure of the stud,' the difference of powder-pressure arising from a change of spiral is noteworthy. Captain Noble tells us that, small as the increment in gaseous pressure due to rifling is, it is still less in the parabolic than in the uniform spiral. Whereas the maximum bursting-pressure is reduced from 19.7 tons per square inch to 19.5 tons per square inch by suppressing the rifling altogether in the case of uniform spirals, the decrement of pressure due to the suppression of the parabolic rifling is a reduction from 19.7 tons to 19.62 tons per square inch. The gain, then, to the powder-chamber from the employment of the increasing spiral, is .12 of a ton per square inch. We commend this philosophical fraction to our artillery philosophers, and would make them a present of this mathematical advantage. When, however, we turn to the Tables of Pressures registered by the Committee on Explosives in the 10-inch 15-ton, which is the subject of Captain Noble's learned investigation, we are rather puzzled to which of the pressures we are to apply the .12 of a ton. We find similar powder-charges, fired under identical conditions, producing most unlike results. We find these anomalous pressures with every description of powder; and we observe that the gun has this parabolic system of rifling, with



D. Van Nostrand, Publisher. New York.

its consequent stud agency. Yet, with these great philosophical advantages, the powder-pressures registered in the 10-inch gun, with 87½ lbs. P. charges and 400 lbs. shot, varied from 25 tons on the square inch to 63.4 tons, the latter expulsive force resulting in the least velocity and striking force in the projectile. Again, 60 lbs. R.L.G. charges, registered powder-pressures varying from 36.5 tons to 57.8 tons on the square inch, under identical conditions, the highest expulsive force imparting the lowest velocity to the projectile. Yet it is on the register of pressures within this gun that Captain Noble's calculations are based. True, he does not select any of the above figures for his formulas, but on the pressures registered with 85 lbs. P. charge, which happened to be 19.7 tons on the square inch. But, if a selection must be made between pressures varying from 19.7 tons to 63.4 tons on the square inch, it might be quite as well to close the Report of the Committee on Explosives, and assume any number of tons at hap-hazard.

"Captain Noble has shown a mathematical gain of .12 of a ton pressure on the square inch by the adoption of the parabolic or increasing spiral. What if the greater part of this astounding increase of pressure from 19.7 to 63.4 tons on the square inch was attributable to the parabolic curve, or, to speak more accurately, to the stud system which that curve necessitates? That gunpowder varies in explosive power in this way in mines, shells, or torpedoes, or anywhere, except in a stud-rifled gun, is stoutly denied. If the variation of powder-pressures be not due to the gunpowder, it must be due to the shot; and if to the shot, then to the oscillations of the axis round the points of contact with the bore, which are exclusively the studs; but the studs are a necessity of the increasing spiral or parabolic groove. Hence it appears that, while saving .12 of a ton pressure on the square inch, by employing this most unmechanical contrivance, we are adding at least 4 tons, and probably more, pressure occasionally to the gun. These are the deductions which we draw from Captain Noble's formulas, and from the Report of the Committee on Explosives, to which we are referred for confirmation of his very able and very interesting but very delusive paper."

In an attempt to remedy some of the evils of the English system, recourse has been had to a single row of studs distributed about the centre of gravity of the projectile; "with results," says the official report, "on the whole more satisfactory." Notwithstanding this, however, the double row of studs seems to be the preferred plan.

If we suppose the projectile to be centered by a single row of studs about its centre of gravity, it will ballot about that point and through an angle double

that which obtains when the shot is centered or lifted at one end. If, however, the projectile were to be centered at its *base*, the rush of gas over it would probably prevent its balloting at all. It has struck me as very singular that the English have never tried the experiment of applying a row of studs to the *base* of the projectile alone. The increasing pitch could then be employed with more advantage, and I have no doubt that such a projectile would prove superior to the present Woolwich shot, and especially to those with the single (middle) row of studs (a singularly unmechanical idea). The system, however, would still be open to grave objections, and the tendency to over-ride the lands in no wise diminished.

Many of those who criticise the Woolwich system, object to it on account of the short length of its groove-bearing, comparing it in this respect with the Scott and similar systems, and attributing its failure principally to this cause. This is also one of the objections urged by Commander Dawson, who, in the conclusion of one of his interesting papers, read at a meeting of the United Service Institution, says:

"The whole of these evils would be obviated by the employment of long bearing centering iron ribs, cast upon and with the projectile, strengthening its walls, and requiring fewer, shallower, and narrower grooves in the gun. A system which in the 7-inch gun competition of 1863—five gave higher velocities, lower trajectories, heavier muzzle blows, and, above all, greater endurance, both to the gun and to the projectile. All this was attained at much less cost and with much greater simplicity. With the *Devastation* class of ships, each costing some £400,000, limited to the employment of four guns, the first of which was disabled by its own French rifling at the sixty-eighth discharge from a cool chamber, this question cannot be said to have reached 'finality.' The point must be reopened, and that soon. It behooves, then, the United Service to study the difficulties of the case; neither discouraged by the lazy cry of 'finality' on the one hand, nor by the angry innuendoes of partisans on the other. The struggle lies between economy, strength, simplicity, long rifle bearings, and perfect centering on the one side, and expense, frailty, mixed metals, short rifle bearings, and non-centering on the other. Let us honestly endeavor to discover experimentally which system will give most work with our well-built guns. From all the official records I have studied, I have no hesitation in affirming that the existing experience is in favor of the simple, inexpensive, and strong long-bearing, and against the expensive, complicated, short-bearing. But let an open enquiry be publicly instituted as to the past experience, and let a fair trial be made, and, as a ruined officer whose professional character is the only posses-

sion left him, I have no hesitation in staking my reputation that the country and the country's service will gain immensely by the victory which I feel assured, common sense will thus gain over obstructive partisanship."

The objections to the short-bearing projectiles are valid as applied to the stud projectile, on account of the difficulty of securing the studs properly, the weakening of the shell by their insertion, and the tendency to override or wedge on the lands; and I think it probable that, if the studs were replaced by ribs, and the uniform substituted for the gaining pitch, as Commander Dawson suggests, the projectiles would be much less likely to wedge or override, and to that extent, endanger less the safety of the gun. But the friction in this case would be very much more than necessary (especially with Scott's or Vavasseur's iron ribs and flanges), and the wedging action would still obtain, the projectile would be imperfectly centered, a more rapid pitch would be necessary*—to compensate for the retarding influence of air upon rotation—and accuracy would be diminished by increased drift, and doubtless, also, by an unsteady exit from the bore. Thus, although I do not agree with Commander Dawson in all of his views respecting the iron-ribbed, long-bearing system of rifling, yet I think it probable that he is safe in predicting its triumph over the Woolwich system if subjected to a fair and crucial test. The argument, however, that "long bearing," or great aggregate length of bearing, is necessary for the successful rotation of heavy projectiles, we know, from our own experience, to be fallacious.

The complaints from English sources respecting the Woolwich system of rifling are quite universal. I have before me numerous English criticisms on the subject, many of which, being somewhat too personal, I do not feel justified in using. The quotations already made, however, will serve to show the very general dissatisfaction which prevails in both military and civil scientific circles in England respecting their "imported and doctored" system of rifling, than which, in my judgment, it would be difficult to conceive a worse.

The following list of Woolwich failures, to be found in the "Cemetery of Suicides" at Woolwich, is furnished by Commander Dawson, R.N., and shows upon what substantial foundation are based the numerous complaints on the subject, from comparatively few of which I have given extracts. This table has been revised, and is admitted to be generally correct as far as it goes; but it is not *complete*, as it comprises the epitaphs of the "suicides" at the "home stations" alone:

* Not more rapid, of course, than the present English pitch, which is excessive.

TABLE XI.

Partial list of English Rifles burst or disabled at "Home Stations." *

DATE.	PLACE.	GUN.		SELF-INFLICTED INJURIES.	CESSATION OF FIRE.
1865	Shoeburyness,	7-in.	7 ton	Upper groove cracked by stud, dented and enlarged tube,	Permanent.
"	do.,	9-in.	$12\frac{1}{4}$ ton	Much worn by gas after 315 rounds,	No.
"	do.,	9-in.	$12\frac{1}{2}$ ton	Cracked grooves and burst, 400 rounds,	Burst.
"	do.,	"	"	Cracked tube, disabled, 1,049 rounds,	Permanent.
1868	Tegel, Berlin,	"	"	Cracked tube, disabled, 311 rounds,	Permanent.
"	Woolwich,	"	"	Explosive burst, by projectile jamming, 1 round,	Burst explosively.
1869	Bellerophon,	"	"	Grooves over-ridden by studs,	Permanent.
"	Redwing,	7-in.	$6\frac{1}{2}$ ton	Muzzle split,	Permanent.
1870	Favorite,	"	"	Grooves over-ridden by studs,	No.
1869	Shoeburyness,	10-in.	18 ton	Grooves burred, bore dented, tube split, 534 rounds,	Permanent.
"	Hercules,	"	"	Muzzle split, 43 rounds,	Permanent.
"	do.,	"	"	Vent damaged, 46 rounds,	— hours.
1870	Staunch,	9-in.	$12\frac{1}{2}$ ton	Bore dented, grooves bored, gun disabled,	Permanent.
"	Royal Sovereign,	"	"	Bore deeply cut into,	— hours.
"	Warrior,	7-in.	$6\frac{1}{2}$ ton	Bore dented, and had to be filed down,	— hours.
1871	Bellerophon,	9-in.	$12\frac{1}{2}$ ton	Bore dented,	No.
"	do.,	"	"	Bore considerably scored by gas, 165 rounds,	No.
"	do.,	"	"	Muzzle coil split,	Permanent.
1870	Shoeburyness,	7-in. / 68-pr.	95 cwt.	Burst violently into 76 pieces, shot jammed, 165 rounds,	Burst explosively.
"	Aldershot,	9-pounder, bronze		Grooves worn away, etc., disabled, 243 rounds,	Permanent.
"	do.,	"	"	Ditto ditto ditto	Permanent.
"	do.,	"	"	Grooves worn by studs, ditto	No.
"	Shoeburyness,	"	"	Grooves over-ridden by studs, bore expanded,	Permanent.
"	do.,	"	"	Ditto ditto ditto	Permanent.
"	Monarch,	12-in.	25 ton	Grooves slightly burred in four guns, average 35 rounds each,	No.
1871	Shoeburyness,	7-in. / 68-pr.	95 cwt.	Grooves enlarged near origin,	No.
"	Woolwich,	12-in.	35 ton	Lower groove cracked by stud from 12 to 25 in. of origin, 68 rounds,	No.
1872	Bellerophon,	9-in.	$12\frac{1}{2}$ ton	? Bore dented, had to be filed down,	— hours.
"	do.,	"	"	Ditto ditto ditto	— hours.
"	Royal Oak,	8-in.	9 ton	Bore dented by projectiles,	No.

"Now, the question arising out of all these disastrous failures, and which underlies the whole subject, is—What is the cause of these severe and injurious strains? Are they inherent in heavy ordnance charges and projectiles, or merely features and defects of a particular system? And in elucidation thereof, it is natural to enquire how the case stands in reference to other guns and systems, and whether they are in these respects better or worse than, or on a par with, the Woolwich or French system.

"But although the objectors we have specially named, and many others, would unite in condemnation of the grooved rifling and studded shot, they are by no means of one accord in assigning the cause, still less in prescribing the

* From English magazine, *Iron*.

remedy. And herein lies the real, the sole, strength of the existing system. Assailed on all sides, it yet holds its ground, not from its own merits, but by virtue of the mere inertia of the nine points of possession.

"And yet, as we shall endeavor to show in succeeding articles, there is no lack of guns and systems well qualified and adapted to supply for us what, it cannot fairly be denied, the Woolwich system has vainly attempted."

It is, I submit, a grim commentary on this "incomplete list," that since the adoption of the Woolwich system of rifling England has enjoyed uninterrupted peace, and that consequently her guns have been fired but a few rounds through a long interval, and many of them doubtless not a shot since proof. Should a war of any magnitude have visited her, it is hard to say what might have been the length of a similar list of "suicides."

4. *The Proposed System.*—The most perfect remedy for the faults of the Woolwich system must, in my judgment, be looked for in the adoption of an entirely new system of rifling and projectiles; and, while I think it probable that in simplicity and efficiency no plan can equal our own improved expansive system—described in the first part of this report—nevertheless the stud system is susceptible of great improvement, and a remedy for many of its defects will, I doubt not, be found in the plan now briefly to be described, and which is essentially the same as that proposed by me in 1870, and practically tested, to a very limited extent, in a 3-inch gun at Leavenworth Arsenal in 1869.

Early in 1870 I had the honor to urge the propriety of firing a relatively light stud projectile from a gun of 15-inch calibre, rifled with a few grooves and a moderate pitch. I argued briefly that the following would be the advantages of such a system:

"It is believed that rifle projectiles will yet be fired from guns of 15-inch calibre. The object in this case is not alone to secure greater penetration—for we cannot afford, perhaps, in guns of such large calibre, to *greatly* exceed the weight of the round shot—but

"1. To secure greater accuracy.

"2. To obtain increased bursting charges.

"3. To generate explosion at the right instant by means of interior percussion fuses, instead of trusting to time-fuses, as must be done with round shell.

"4. To ensure penetration of armor, even when struck at extreme angles.

"5. To obtain uniformity of pressure (strain), velocity, and range for uniform charges of powder, which can be done by giving the projectile bearings, front and rear, upon which it can slide out of the piece without jar.

"6. As much increase of penetration as is due to increased weight and better-maintained, if not equal, velocity.

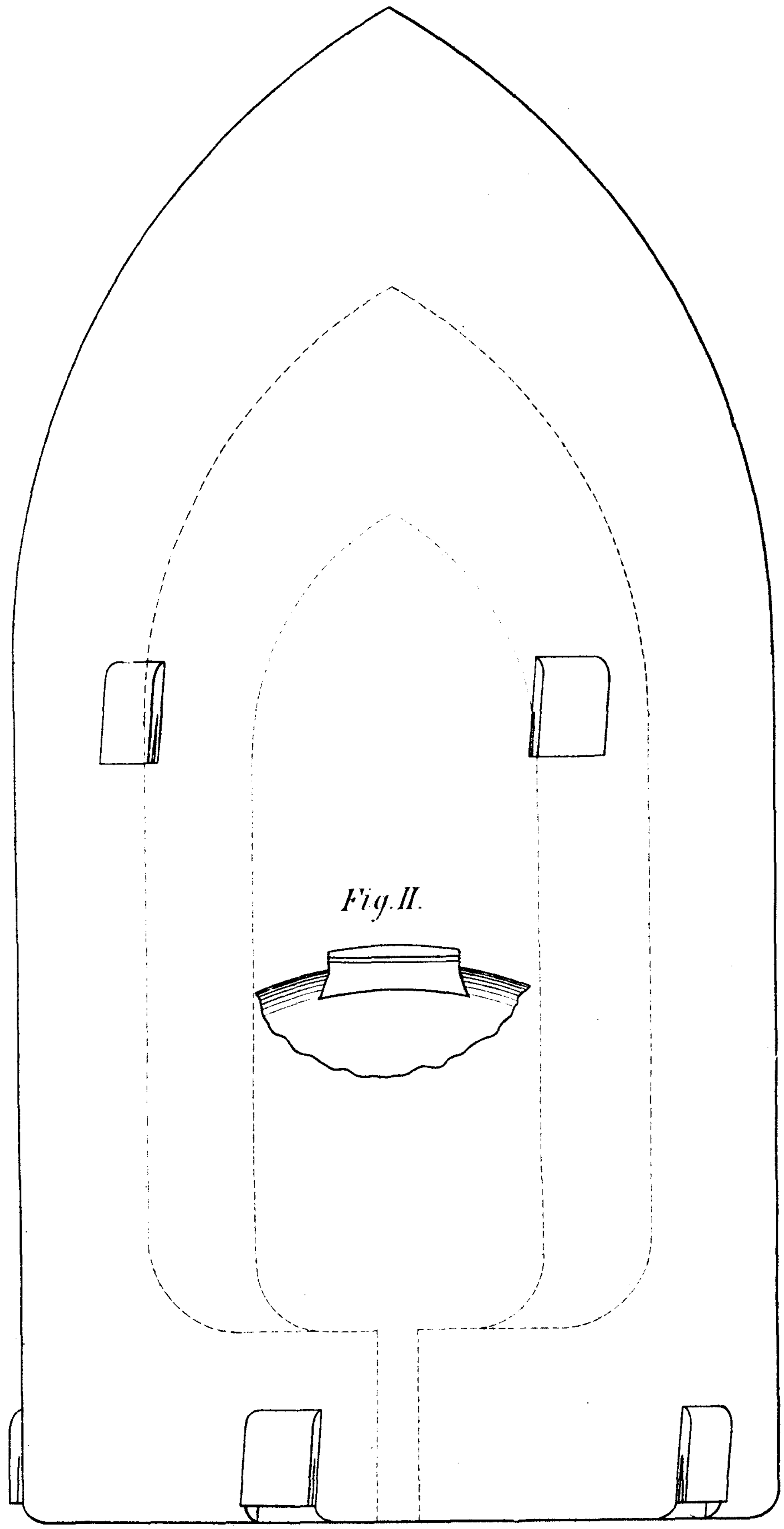
"While fully admitting the tremendous power of our large smooth-bore guns, the time is assuredly approaching when rifled guns, of like calibre, will be found to possess at least equal endurance, be much more general in their application, and have superior powers of destruction.

"Such a system of rifling would not interfere with the efficient use of spherical projectiles when they were deemed to possess sufficient power for the occasion."

This proposition, which appeared in two or three publications in the spring of 1870, differs principally from that which Mr. Norman Wiard is now urging upon the attention of the Ordnance Department in two important particulars: 1. Mr. Wiard proposes the old French experimental plan of two rounded grooves, while I proposed "a few grooves only"; 2. Mr. Wiard proposes to rifle our present 10-inch and 15-inch guns on his plan, at a rather extravagant price, and to fire from these guns a sort of winged or flanged projectile of the same weight as the round shot; while I proposed simply to make all *future* guns of 15-inch calibre somewhat heavier, and, without injuring their efficiency as smooth-bores, to so rifle them that we might reasonably undertake to fire an elongated projectile of somewhat greater weight than the round shot, but still not so heavy as a regular elongated projectile of the same calibre.

Having reconsidered this subject, I am convinced that, while the model of our present 15-inch gun could with propriety be slightly changed, by throwing the maximum diameter further forward and slightly increasing the weight and length of the gun, on account of the large charges of slow-burning powder now employed; yet that, if a 15-inch *rifle* be procured, it should weigh at least fifty tons, and the projectile not less than 1,000 pounds. Plate XXIII. shows the character of one of the projectiles for a 15-inch rifle, proposed in my report of 1870, and Fig. II., Plate XX., shows forms of *papier-maché* or wooden sabots, which can be used to lift the round shot off the rifling when it may be thought advisable to fire spherical projectiles from this or any other rifle of large calibre. Captain Parrott has, I believe, used papier-maché sabots in his rifles with good effect.

I do not propose to criticise Mr. Wiard's proposition in detail, but will simply remark that his scheme seems wild and impracticable. His proposed projectile cannot but prove extremely inaccurate, is absolutely unfit for long ranges, will doubtless strain the gun—not simply by increased powder-pressure and a tendency to upset, but by a wedging action in the grooves similar to that



Projectile for a light 15 Inch Rifle.

Proposed Jan'y 1870.

D. Van Nostrand, Publisher. New York.

of the Woolwich projectile; while the slight possible gain in penetration near the muzzle of the gun—when his shot happens to strike fairly—will not compensate for a single one of the disadvantages mentioned. In fact, the projectile is so extremely liable to upset in the bore, that the gun will be endangered at each discharge. The employment of three grooves instead of two, would at least tend slightly to correct this fault, but the system would still remain worse than worthless.*

The Projectile.—The proposed projectile is shown on Plate XXI. It is provided with the requisite number of studs, which are secured in the projectile by undercuts in the usual manner. The studs are formed as shown in the drawing; and, after insertion in the projectile, each stud is split, or cut, half or a third way through its length—by means of a saw or suitable tool—in a plane tangent to the cylindrical surface of the projectile, at the middle portion of the stud. The forward portion of each stud is left solid, the top edge being rounded toward the front, and the side edges straight and in planes parallel to the inclination of the twist. The height of the studs above the surface of the projectile is the same as the depth of the grooves. This will allow, in loading, the same windage over the studs as between the lands and the projectile. The studs are also left about one-tenth of an inch narrower than the grooves, so as to ensure their ready entrance in loading. As much more play may be allowed as is necessary; but the more the lateral play of the studs, the greater the windage. If the number of grooves is even, the front and rear row of studs may alternate in the grooves—*i.e.*, the studs may be arranged in quincunx order; otherwise, the studs should be arranged in pairs, and the two rows should not be too close together. The material of the studs should be fine brass; or, a composition of copper, twenty-five parts, to one part of tin, would probably answer.

The Rifling.—For the projectile on Plate XXI., having two rows of studs, the pitch of the rifling should be uniform, the grooves square—*i.e.*, their sides should be parallel—the bottom edges of each groove very slightly rounded, and the edges of the lands rather sharp. For the projectile on Plate XXII., having a single row of studs, the pitch of the rifling may be increasing, if desired; and, in fact, in all cases where the front row of studs is dispensed with, the increasing (compromise) pitch is recommended. Further details of the proposed rifling are

* It is altogether probable that a 10-inch gun converted into a rifle of smaller calibre—after the manner of Parsons or Palliser—by the insertion of a tube of wrought iron or steel, as has been proposed to the Department, would yield far greater endurance, and develop at least *double* the power and range (apart from superiority of accuracy), than would a similar gun "converted" on the plan proposed by Mr. Wiard.

given in the following table. It is possible that, in the larger calibres, the number of grooves could be reduced with some advantage to the gun and projectile; but for a first experiment I would prefer to adhere to the details as here given:

TABLE XII.

Proposed plans of rifling for expansive stud projectiles.

Calibre of Gun.	Number of Grooves.		Width of Grooves.	Depth of Grooves.	Radius of Curve.		Pitch of Rifling.		
							Single Row of Studs. Increasing.		Double Row Uniform.
	For Single Row of Studs.	For Double Row of Studs.			At Bottom Edge.	At Top Edge.	Commencing.	Ending.	
Inches.			Inches.	Inches.	Inches.	Inches.	Calibres.	Calibres.	Calibres.
3	3	3	0.70	0.15	0.020	0.005	72	36	36
3½	3	3	0.75	0.16	0.020	0.006	76	38	38
4½	5	6	0.80	0.17	0.025	0.007	86	43	43
5	5	6	0.85	0.18	0.025	0.008	90	45	45
6	5	6	0.90	0.19	0.030	0.009	98	49	49
7	5	6	0.95	0.20	0.030	0.010	106	53	53
8	7	8	1.00	0.21	0.035	0.011	112	56	56
9	7	8	1.05	0.22	0.035	0.012	118	59	59
10	7	8	1.10	0.23	0.040	0.013	124	62	62
11	9	10	1.15	0.24	0.040	0.014	130	65	65
12	9	10	1.20	0.25	0.045	0.015	136	68	68
13	9	10	1.25	0.26	0.045	0.016	144	72	72
14	11	12	1.30	0.27	0.050	0.017	150	75	75
15	11	12	1.35	0.28	0.050	0.018	156	78	78

The Action of the Projectile.—The projectile is inserted in the bore by "feeding" a stud to each groove. The bearing on either side of each stud being square, and the studs fitting loosely in the grooves, the projectile may always be loaded with facility. Upon discharge, the early effect of the powder-gases is to expand the upper lip (Fig. II., Plate XXI.) of each stud into the full depth of the groove. The upper lip of each stud in the front row is also expanded by the gases which pass freely through windage and the unoccupied grooves. It may be thought that in the position of the projectile in the bore, those studs in the upper part of the projectile will be further distended than the rest, and that therefore the projectile will not be properly centered; but experience has proved that the utmost uniformity obtains in the expansion of the studs—as indeed was to be expected from the fact that the projectile is a mere feather when compared with the tremendous forces surrounding it. The projectile, therefore,

speedily adjusts itself within the bore; and a smooth and steady flight, and an examination of recovered projectiles, afford ample proof of a uniform and regular distension of the studs, and consequently of the accurate centering and smooth passage of the projectile through the bore of the gun.

Doubtless such a projectile will always pass through the gun with a minimum amount of friction. It is obvious that not the slightest wedging effect is exerted, as, the sides of the studs being square, and the bearing of each stud full and perfect, the rotating force is applied by each groove in the most direct and economical manner—*i.e.*, in a direction normal to the radius of the projectile at each stud. The grooves, therefore, in such a system, perform their simple duty of rotating the projectile, which is kept centered throughout the bore by the distension of the expansive portion of each stud, without bringing the slightest additional strain upon the gun.

"For, the projectile leaving the gun with a mechanical fit, front as well as rear, balloting and wedging are effectually prevented, the coefficient of friction becomes as invariable as in a machine, pressure and velocity will always bear their due relation, and the only cause for variation in either will be due to the irregularity of the charge itself in quantity or quality.

"The studs are made so low as to allow the projectile to be loaded with the greatest facility; yet stripping is rendered impossible, for the first effort of the discharge is to lift the studs into the grooves, securing thereby the full benefit of the same, and keeping the contact absolutely perfect so long as the projectile remains in the gun. As long as attrition of the studs continues they are kept in fresh contact with the bottoms of the grooves by the continued action of the gases; the studs thus retaining a maximum distension, the shot is well lifted, the bearing in each groove full and perfect, and the rotation of the projectile fully assured." *

In case of any unlooked-for obstruction or fouling in the grooves of the gun, the studs will yield, instead of opposing a rigid resistance to the obstruction. Wedging will thus be effectually prevented.

The Single Row of Studs.—The attempt to employ a single row of studs in the Woolwich system has already been alluded to. In that system I suggested that balloting might be prevented by shifting the studs from the centre to the base of the projectile, although wedging and overriding would remain uncorrected evils. In the proposed system, however, wedging and overriding are alike impossible, for the reason that the bearing of each stud in its groove is full, perfect, and radial. In the case of the double row of studs, when both ends of

* *Vide* my report of 1870.

the projectile are centered in the bore, balloting of course cannot occur. Practically, however, I believe that the front row of studs may be dispensed with without in a sensible degree affecting the efficiency and accuracy of the projectile. I have claimed that the allowance of a moderate windage over an expansive projectile, centered only at its base by its sabot, will effectually prevent balloting, and, if such is the case, it is clear that a stud-projectile centered in the same manner—but by a row of studs which may be arranged to allow any desired gas-escape—must have an equally smooth passage through the bore. A number of 3-inch projectiles of 11 pounds, and 8-inch of 150 pounds, having a single row of expansive studs around the base, have been fired experimentally, and, as was the case with the expansive projectile described in the first part of this report, every flight was perfectly smooth and even; and I have no reason to doubt that a failure in this respect would be as exceptional and rare as when the double row of studs is employed. With the single row of studs, the grooves of the rifling may be quite shallow, since the studs may be split *before* inserting them in the base of the projectile, as in Fig. II., Plate XXII., where the cut is seen to be below the surface of the projectile.

I have already stated that I consider the increasing pitch inapplicable to the double row of studs. The single row, however, while proving ample to rotate the heaviest projectiles, is at the same time equally well adapted to any character of twist. While, therefore, the uniform pitch should be employed with the former projectile, with the latter I would recommend a moderately gaining pitch, such as is given in Table XII.

Should it be the decision of the Department, therefore, to rifle any of the proposed experimental guns for the use of studded projectiles, I respectfully suggest the trial of the system herein described in one of the two forms discussed:

1. The projectile on Plate XXI. or XXIII., and the rifling of uniform pitch given in Table XII., or

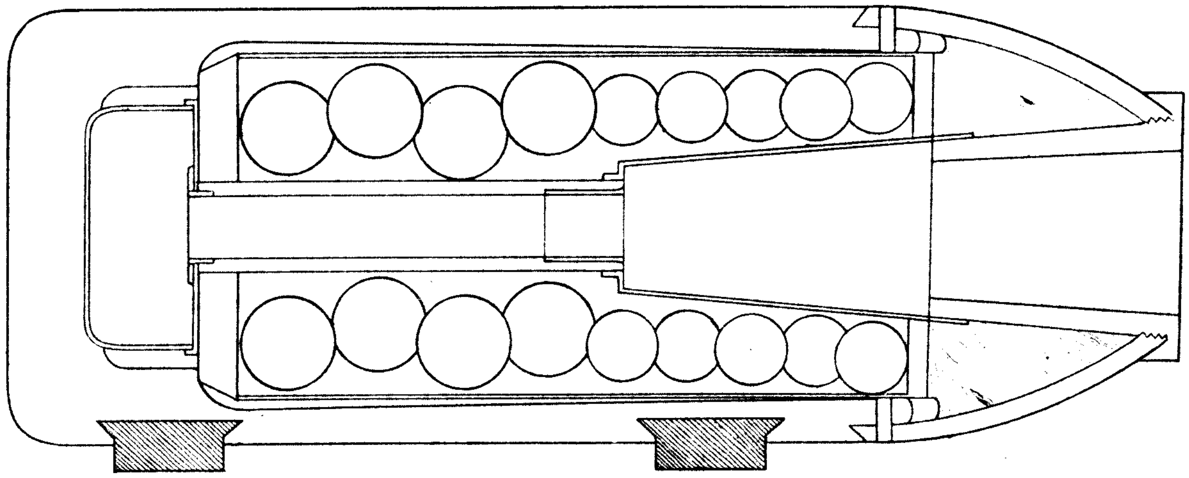
2. The projectile on Plate XXII., and the rifling of increasing pitch commencing with half the ultimate value, as given in Table XII., except that the grooves may be one-third less deep, if the stud shown in Fig. II. be used.

The adoption of either of these plans would, I think, develop superior advantages over any system of *fixed* or *rigid* studs and *rounded* grooves.

Field. Shrapnel.

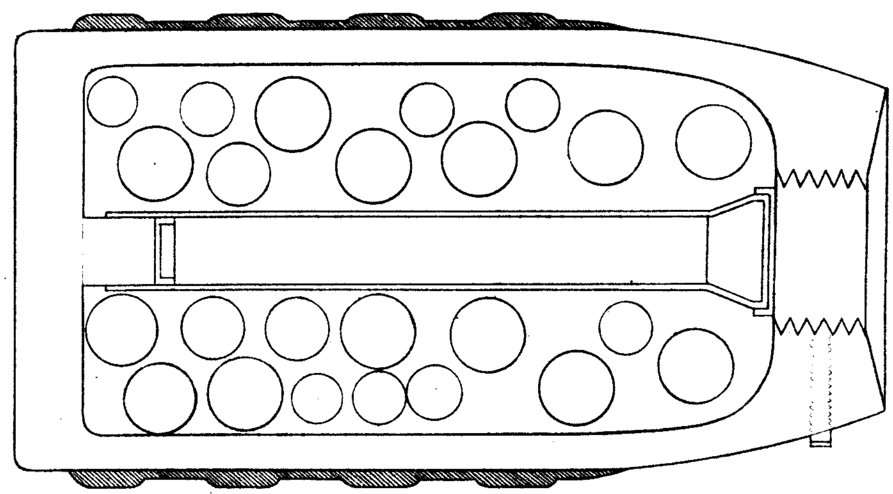
ENGLISH

For 3^{in} Rifle.



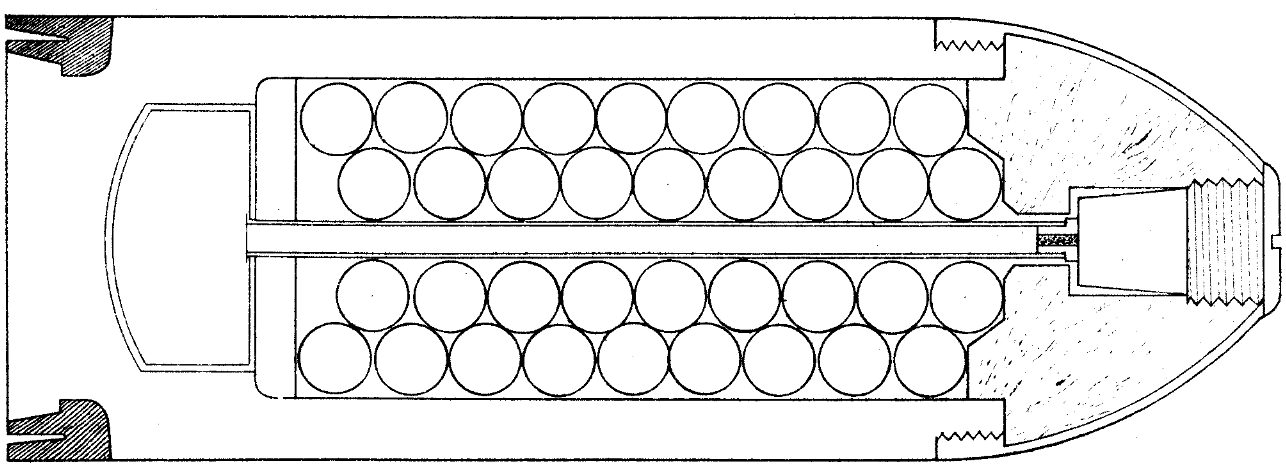
PRUSSIAN

For 3.45^{in} Rifle.



AMERICAN.

For 3^{in} Rifle.



D. Van Nostrand, Publisher. New York.

CAST-IRON RIFLES OF LARGE CALIBRE.

"My belief is that after we shall have procured a projectile that is as certain in its operation in the rifled gun as the round shot is in the smooth-bore, we can, by firing to extremity one or two 12-inch rifles, fix a limit within which the gun may be considered as absolutely safe; but it will require experiment to fix that limit.

"RODMAN."

The failure, under very disadvantageous circumstances, of one or two cast-iron rifles of large calibre, has had the effect—notwithstanding the admirable endurance of smaller guns of the same class—to lessen very greatly public confidence in cast iron as a material for heavy-gun construction, and a majority of ordnance officers to-day would probably pronounce cast iron unfit for heavy rifles; while some, I am aware, consider that even for smooth-bores it is to be distrusted. I maintain this to be an unjust or at least hasty verdict, based on unfair trials, the true merits of which have never been properly understood, save by three or four officers, who, while fully aware of the unsatisfactory nature of the trials and the severe tests to which our few experimental guns had been subjected, have nevertheless, until recently, been unable to devise the proper remedy. Already Rodman had introduced his large-grained, perforated cake, and prismatic powders with encouraging results, but a continuation of experiments indicated that the problem was but half solved.

The original question which presented itself for solution may be stated as follows: Given a gun of which it is desired to properly test the endurance, to find a powder which will yield maximum velocities with minimum or moderate pressures, and a practical projectile * which, at every discharge, will oppose in its passage through the bore an invariable resistance to the action of the charge, whereby such an uniformity of results shall be obtained as will enable us to form

* A close-fitting cylinder might conduce to the desired result, but, not being a *practical* projectile, would establish no criterion of the performance of the gun in actual service.

a fair judgment as to the probable endurance of similar guns under like circumstances. The introduction of large-grained, slow-burning powder, therefore, solved just half the problem; it served to diminish the *average* pressure brought to bear in our large guns, but it proved no safeguard against frequent irregularities on the part of the projectile, such as balloting, wedging, breaking, etc., to which could clearly be traced pressures so enormous as to vitiate in a moment all previous results, and render it simply impossible to base any practical conclusions upon them, or form even a reasonable conjecture as to what the guns *would* stand, provided they were not liable to the occasional "anomalous results" of an enormous powder-pressure and a reduced velocity. One such pressure and one such wedging strain might ruin a gun which otherwise—that is, if subjected only to such strains as it was calculated to withstand—would yield a handsome endurance.

To attain the desired uniformity of results in proof and service, but one plan now presented itself, namely, the devising of such a system of rifling and projectiles as would ensure to the latter infallible uniformity of action for given charges of the same powder. Failing to attain this, there would then remain but the recourse of attempting to produce a gun so strong as to be able to successfully withstand the enormous strains from which we are obliged to confess our inability to protect it. In this direction vast sums have been expended, and powerful guns of costly materials and construction have been built, only to fall victims, sooner or later, to a vicious system of rifling and a faulty projectile.*

I have every confidence that either of the muzzle-loading systems previously recommended will prove entirely reliable; and it is clear, if such should prove to be the case, that it will afford us for the first time an opportunity of fully and fairly testing the merits of our cast-iron rifles. I therefore urgently recommend that if the new expansive projectiles continue to give perfect satisfaction—after embracing in their record some of 12-inch calibre—the Department endeavor to procure a cast-iron rifle of large calibre *and proper weight*, with a view to the practical determination of so important a question as the endurance of such a gun under fair conditions of service.

Before discussing further the merits of this proposition, it may be well to consider briefly the record of our cast-iron guns. To this end I have extracted

* It would require millions of money and years of time to establish a Woolwich or an Essen in this country. Congress will never appropriate an amount sufficient for such a purpose, nor even the yearly million to keep such an establishment in operation.

the subjoined record from the firing reports at this post;* and as even the smooth-bores have fallen under suspicion, and as their history also embraces the record of many heavy pressures incurred during experiments with powder, I will include a few of them in the following résumé. The 8-inch and 10-inch Rodman guns have shown extraordinary endurance, and, being generally acknowledged the finest smooth-bore guns of their calibre in any service, further reference to them is unnecessary.

1. A 15-inch gun at Fort Monroe endured 416 rounds before bursting, served generally with 100 pounds of powder and a solid shot of 450 pounds. During this firing all kinds of experimental powders were tested, some varieties giving the very high pressures of 50,000 pounds to 80,000 pounds per square inch.

2. Two 15-inch guns, cast at Pittsburg recently for the navy, were fired to extremity, enduring upwards of 600 rounds each, with 100-pound charges and solid shot. The powder used gave a much higher average pressure and greater irregularity than does our present standard—*i.e.*, that of more recent manufacture. One of these guns was cast solid, the other hollow, the latter showing a slight superiority. Concerning the hollow-cast gun, its manufacturers, I believe, considered it in a measure unsatisfactory, owing to a want of recent experience and the loss of some skilled workmen during several years of idleness in gun-casting. Moreover, it was cooled by a current of air instead of water, and therefore (although the use of air was suggested by Rodman) could not be regarded as a fair representative gun of the Rodman system. Nor does there appear any evidence that the Navy Ordnance Department made any stipulation, or even tests, as to the initial tension of the casting; and it is doubtful to my mind if air-cooling would yield as much as one-third of the initial tension which theory, confirmed by practice, has shown to be important. Nevertheless, the gun attained to over 600 rounds. This good record, I think, may be attributed to the fact that, although the powder employed was unnecessarily violent, the "proof" was conducted ***consistently throughout as an endurance test***, and all outside experiments or departures from the set programme properly excluded.

3. The 15-inch gun, No. 19, now mounted at Fort Monroe, has been used exclusively for experimental purposes (testing powder and carriages), and has, therefore, not been subjected to regular proof. Many kinds of powder have been fired from it, such as "Mammoth," "block," "lense," "perforated cake," "square," and "hexagonal." Some three hundred rounds have been fired, with charges of from 100 to 125 pounds of powder and solid shot of 452 pounds, and

* Fort Monroe Arsenal, December, 1872.

a few rounds with charges somewhat lighter. This gun, as would naturally be the case from not receiving fixed treatment, has frequently been subjected to high pressures.

During our recent war the 10-inch and 15-inch Rodman and the 9-inch and 11-inch Dahlgren guns in the army and navy were fired more frequently than any similar number of heavy guns have been fired in any European war, and, it is possible, quite as often as any future war may necessitate; yet not one was disabled nor in the slightest degree impaired. One 15-inch gun only, used experimentally on the proof ground, was so far injured by some of the high-pressure powders tested in it as to reveal within a hundred rounds a crack in the bottom of the bore, after which firing with it was discontinued. On this gun a cannon-lock was used, which closed the vent on the exterior, and General Rodman ascribed an injurious tendency to this plan.

4. An 8-inch Rodman gun, rifled with five ribs which fitted into corresponding grooves cut through the entire cylindrical length of the projectile, endured under this vicious system 88 rounds, but had to give way, owing to the heavy and long-sustained pressures and strains to which it was subjected.

5. Another 8-inch Rodman rifle (expansive system) endured successfully 1,046 rounds, bursting at the 1,047th round, under a pressure of 150,000 pounds per square inch, caused, it was thought, by the stripping and wedging of an experimental projectile. The record of firing embraces many pressures, approximating 100,000 pounds per square inch.

6. An 8-inch Rodman rifle, the mate to the last-mentioned gun, has been fired 864 times, and is yet serviceable. The bottom of the bore is marked with a very light net-work of cracks or seams, but the lands and grooves of the bore are as sharply defined as ever. In this gun 205 pressures have exceeded 50,000 pounds per square inch, 135 pressures have exceeded 75,000 pounds, 16 pressures have exceeded 100,000 pounds, 4 pressures have exceeded 125,000 pounds, and 3 pressures have reached 150,000 pounds per square inch.

7. I will next mention a 12-inch Rodman rifle which endured, before bursting, 472 rounds. This gun was fired with 70-pound charges and projectiles of 500, 600, and nearly 700 pounds. All sorts of experimental powders and projectiles were employed; great numbers of the projectiles "stripped," "wedged," and "upset," and very many pressures exceeded 50,000 pounds, 70,000 pounds, and 90,000 pounds per square inch. The projectiles recovered showed marks of the lands, in some cases throughout the entire length of their cylindrical portion, and in other instances quite deep impressions of the rifling were found upon the forward end. Of many pressures no record was kept.

8. The 12-inch Rodman rifle which burst last September at the twenty-seventh round, under a pressure of 100,000 pounds (due, as I maintain, to a stripped and wedging projectile), had been subjected at the sixth and seventh rounds, by the wedging of the projectile (which was thereby deeply indented), to the enormous pressures of 240,000 pounds per square inch, and some twenty subsequent pressures, ranging from 50,000 pounds to 150,000 pounds, the higher pressures being clearly traceable, in my opinion, to the misconduct of the projectiles. This gun was so unfortunate as to meet with a rapid succession of the strains to which, from causes previously explained, our cast-iron rifles have hitherto been constantly exposed. At the sixth and seventh rounds, above quoted, the charges were increased from 60 to 70 pounds of Mammoth powder. The result was in each case *quadruple* the pressure, and absolutely 100 feet *less* velocity.*

In consideration of this record, it should not be lost sight of, 1, that not a single one of these guns has been regularly *proved* by fixed charges of standard powder and good projectiles, but that all sorts of experimental powders and projectiles have been employed, resulting frequently in strains that would be liable to burst the strongest guns; 2, that all our guns have been *too light*—the 12-inch rifle, for example, albeit of cast iron, is from 28,000 to 30,000 pounds lighter than the built-up 12-inch steel gun of Prussia or the 12-inch built-up wrought-iron and steel gun of England; 3, that this record comprises our *first attempt* toward the production of heavy rifles of cast iron. Compare this record of a first attempt with the early efforts of England, Russia, Prussia, and France, and there will be seen abundant encouragement for further and more fairly-conducted trials.

It is my belief that a 12-inch rifle, constructed on the Rodman plan, of proper weight, properly rifled, and fired to extremity with our improved powder and projectiles, would develop excellent endurance, and could be depended upon for at least 500 rounds with 100-pound charges of improved powder and projectiles of 600 pounds (meeting, as previously explained, any demand for an increased weight of projectile by a corresponding increase of calibre); and I think that a careful consideration of all the disadvantages attending our previous trials of cast-iron rifles, and of the great powers of resistance therein developed, together with our present improved facilities for the application of fair and proper tests, will convince even the opponents of the Rodman system that further trials are imperatively needed to definitely determine the merits of cast iron for heavy rifled guns.

* See early pages of this report.

It is thought that Congress would appropriate moderately, year by year, for these guns, if it can be clearly shown that their procurement would be a judicious expenditure of public money. There is, of course, but one way of showing this, and that is the practical one of proving such guns to be reliable; and we should lose no time in establishing this fact or the contrary. Assuming it desirable to fire projectiles of at least 700 pounds in weight, I therefore respectfully urge that earnest efforts be made to procure at least one Rodman gun of 13 inches calibre, weighing at least 80,000 pounds, and rifled on the plan already described; and that, if procured, the programme for its proof be something as follows:

1. Determine as nearly as possible a large-grained powder of suitable density and granulation, using for this purpose the light 12-inch rifle now at Fort Delaware.

2. Determine at the same time and by the same means, as nearly as possible, the correct dimensions and proportions of the projectile.

3. Fix the weight of the projectile at 770 pounds, and commence the proof of the 13-inch by gradually increasing the charge until a satisfactory velocity be attained, or until the powder-pressure reaches a certain limit, say 35,000 pounds per square inch, since we know that high velocities are attainable with such pressures.

4. Having determined on a satisfactory powder, it will probably be found that charges of 130 pounds will impart to the projectile of 770 pounds a velocity of at least 1,350 feet, with pressures not exceeding 35,000 pounds per square inch as a maximum. Still better results would probably obtain with cake or prismatic powder, although this would give a total energy of 9,727 foot-tons, as against 8,213 foot-tons, the maximum service effect of the English 35-ton rifle, and complete penetration of over fifteen inches of solidly-backed wrought-iron plate.

5. Having determined on a satisfactory charge of powder (in kind and weight), adhere to it rigidly as a standard throughout the trial; and, furthermore, for at least 600 rounds, if the gun endure so long, let no change be made in the weight or character of either powder or projectile.

So simple a programme, rigidly adhered to, will afford a vast amount of useful information, and will furnish the only practicable and convincing proof of the fitness or unfitness of cast iron for rifles of large calibre.

Should it be found that but three or four hundred rounds constituted the "life" of such guns, yet, as the simplicity of their construction would probably ensure *uniformity of product*, and the good character of the projectiles and powder *uniformity of endurance*, I would consider such a result as fully justifying the

immediate procurement of these guns in large numbers for coast defence. Disregarding the possibilities of the system for improvement, and bearing in mind simply such a record, the necessary expenditure could not be thought unwise merely because at some future day it might be found that for double the money we could procure stronger guns. During even a protracted war, it is altogether improbable that any dozen of such guns would half exhaust the most moderate estimate of their endurance.

The "battle of the guns" is not yet fought out. Will it ever be so? It is folly, I submit, to await the decision of so doubtful a conflict, and it behooves us to determine absolutely, and without delay, whether we have not within our own resources—nay, if we have not already available in the Rodman process—a cheap, reliable, and efficient system of heavy-gun construction.

Time and Percussion Fuzes.

LETTER TO THE CHIEF OF ORDNANCE, DECEMBER, 1872.

Some two or three years since I had the honor to submit for your consideration certain forms of time, percussion, and combination fuzes, which I then considered might possibly prove acceptable substitutes for those in service. Having recently somewhat modified these fuzes, and applied some of them to drawings accompanying my report on projectiles and rifling, it may be well to present the following explanation of the same, accompanied with drawings in sufficient detail. A great amount of ingenuity has been expended in attempts to produce an entirely satisfactory fuze, but hitherto with indifferent success. I cannot promise that the plans here presented will be more successful, but submit them as likely, in my judgment, to give good results.

Referring to the 3.5-inch shrapnel on Plate III., it will be seen that I have provided it with a *percussion*-fuze. I am aware that this will seem like an innovation on the practice of service, which has heretofore restricted the use of percussion-fuzes altogether to shells, it being generally considered impracticable to employ any other than a time-fuze with the more deadly shrapnel. That in nine cases out of ten the percussion-fuze would prove more efficient in such projectiles, I have long been persuaded; and the Prussians would seem to have tested the question practically, since a large proportion of their rifle shrapnel is provided with the percussion-fuze. But before discussing the relative merits of the time and percussion-fuze, I will briefly describe those here presented.

The fuze shown in the projectile on Plate III. is seen to be a simple modification of the ordinary percussion-fuze, substituting for the usual plunger and percussion-cap a centre-primed plunger, practically a centre-primed cartridge, which, darting forward upon the impact of the projectile, strikes a firing-pin, N,

Fig. I.

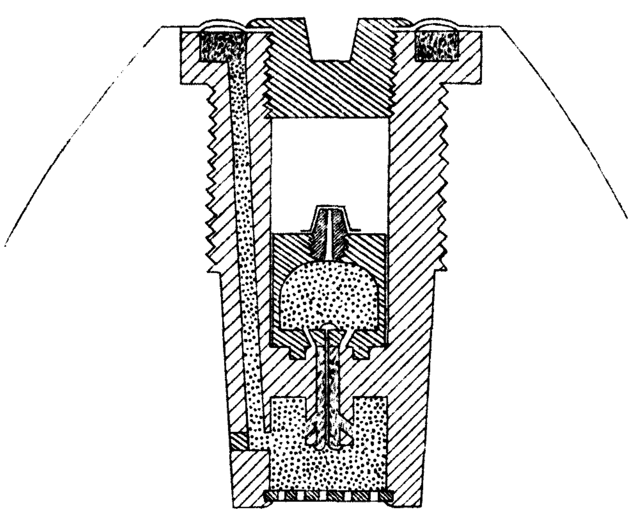


Fig. II.

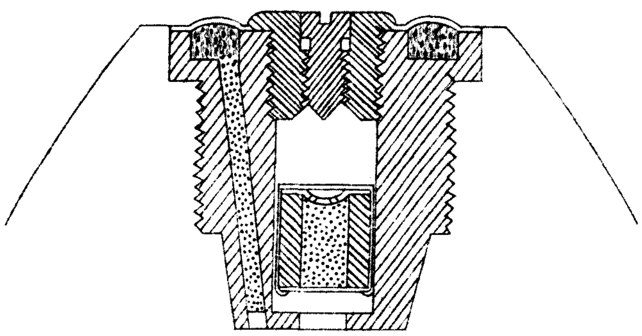
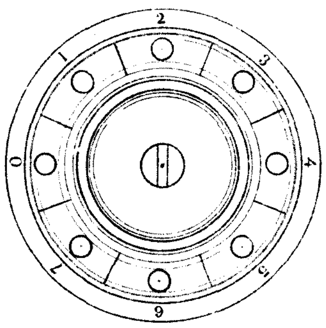


Fig. III.



D. Van Nostrand, Publisher. New York.

in the screw-plug, S. The usual safety-wire is broken by the shock of discharge, and, for additional safety in transportation, the plug, S, may be reversed, or a pin may be arranged so as to be withdrawn before firing.

Fig. I., on Plate XXV., represents a combination-fuze. The plunger is seen to be hollow; its bottom is perforated, and attached to its centre is a friction-wire. Should the friction-wire fail, and the percussion arrangement succeed, the explosion of the fine powder with which the plunger is charged communicates ignition to the lower chamber. Both failing, the time arrangement may succeed. The time-fuze composition is arranged in a circular channel, as in the Borman fuse.

Fig. II., Plate XXV., shows a combination-fuze arranged on the same principle as that just described. In this case the friction-wire is dispensed with.

Plate XXVI., Figs. I., II., and III., represents a form of combination-fuze which I think would prove efficient. The fuze-stock embraces three parallel cylinders. In one is fixed a percussion arrangement, in another a time arrangement, and both have communication with the third cylinder, which is charged with fine powder. As is shown in the drawing, this magazine may be fired either by the action of the percussion-fuze, or by having one of the openings, arranged spirally about the time-fuze, brought opposite one of the vertical series of holes communicating through the diaphragm with the magazine. The usual paper time-fuze is first placed in the brass receiver (which is easily revolved and secured in any desired position), and then tapped through the openings of said receiver. The openings through the diaphragm may be filled with powder-paste. It would probably be well to shorten the percussion arrangement, in order to restrict the forward movement of the plunger to the shortest practicable limit.

If elongated projectiles could be relied upon to strike invariably "end on," or point foremost, the construction of a satisfactory percussion-fuze would present little difficulty; but this is the case only with projectiles of the larger class, intended to be used against fortifications, ships, etc. In field-firing, and in many cases of bombardment, the projectile, keeping parallel to itself, and departing more and more from a tangent to the trajectory, must, unless it strike an obstacle, like a tree, a house, or hill-side, strike first upon its side, and, when the ground is level, with a sort of "heel-and-toe" movement; and there is little doubt that on the battle-field fully nine-tenths of the projectiles are liable to strike in this manner. The consequence is so slight a check in velocity that the plunger does not move forward with sufficient force nor quickness to cause explosion, added to which difficulty is the liability of the fuze-stock to bend, as

shown at *A*, Fig. III., Plate XXVII., in which case it will be impossible for the plunger to move forward, *upward*, and past the obstruction at K, where the bend occurs. In great part this objection might be obviated by shortening, and thereby stiffening, the fuze, as in Plate III.; and I am well assured that the unsatisfactory action of our percussion-fuzes during the late war may be ascribed, in part at least, to their unnecessary length. As a more perfect remedy for these defects, I have designed the fuzes shown in Fig. IV., Plate XXVI., and Figs. I. and II., Plate XXVIII. Referring to the last-mentioned, F is a fuze-stock screwed into the *base* of a projectile, P is a plunger, C a centre-primed magazine, and *a* is a safety-wire which is broken, by the inertia of the plunger, upon discharge. If the projectile strike end on, the plunger will of course dart forward and explode the magazine, or centre-primed cartridge, C, which ignites the charge by blowing off the cover or disk, I. If, however, the projectile strike upon its side (see Fig. III., Plate XXVII.), the fuze-stock is bent downward; but as the bend occurs *behind* the plunger, at the neck of the stock, N (the stock being purposely weakened at that point), the free motion of the plunger is not interfered with, but, on the contrary, is assisted, by the downward inclination of the channel.

Figure I., Plate XXVIII., represents a concussion-fuze which, it is thought, will operate successfully, whether the projectile strike end on or sidewise. F is a fuze-stock, having a plunger, P, secured to it by means of a screw, S, operated by a key K; *a*, *b*, and *c-d* are rough or serrated "friction-wires," passing through channels in the plunger, which may contain also two or more side or lateral channels primed with friction composition. The friction-wires are secured firmly at *a* and *c*, and more lightly at *b* and *d*. The fuze-stock is screwed tightly into the base of the projectile, and is provided with a lead washer, *w*, and gas-check of copper, *G*. As shown in the drawing, the fuze is secured for transportation. Before firing, the key, K, must be turned to the left by means of a screw-driver, until the screw, S, reaches the bottom of the tenon in the key, when it can be moved no further in that direction, which fact indicates that the fuze is ready for firing. On the contrary, if the key be turned to the *right* until it stops, we know the fuze to be prepared for transportation. The fuze being ready for firing, if the impact of the projectile be direct, the plunger, P, darts forward from its seat and into the charge, the friction-wires being drawn through it, and thereby igniting the composition in the channels. Should the projectile strike first on its side (A), the plunger will drop downward, hinging about a point *o*, and, withdrawing the opposite wire, *a b*, thus effect ignition. The general tendency of the plunger will be downward and forward.

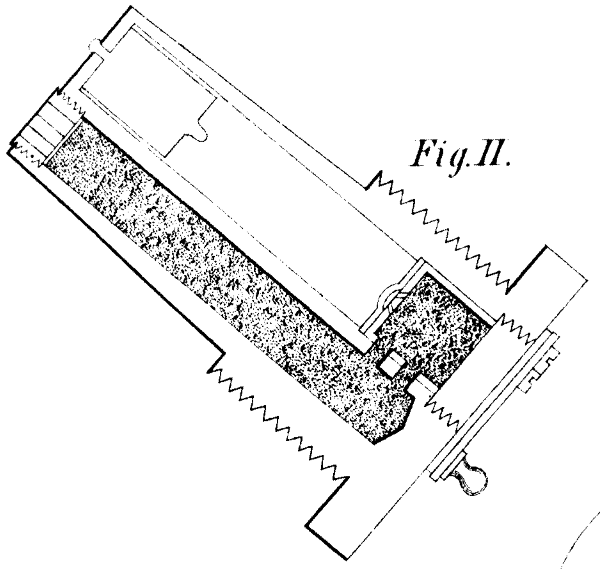


Fig. II.

Fig. III.

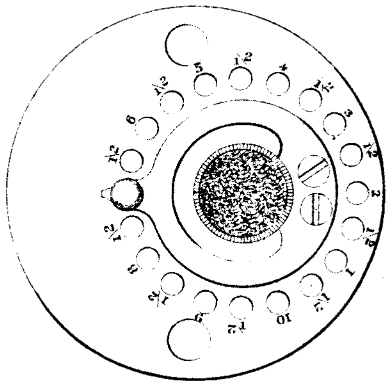


Fig. IV.

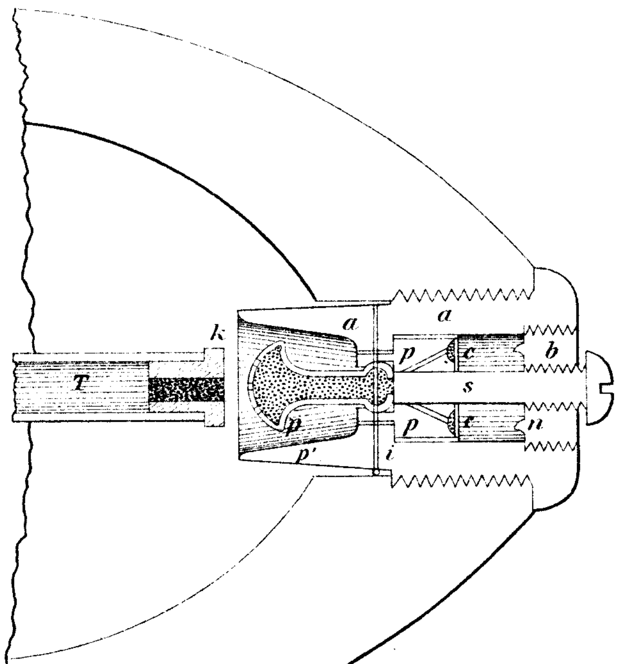


Fig. I.

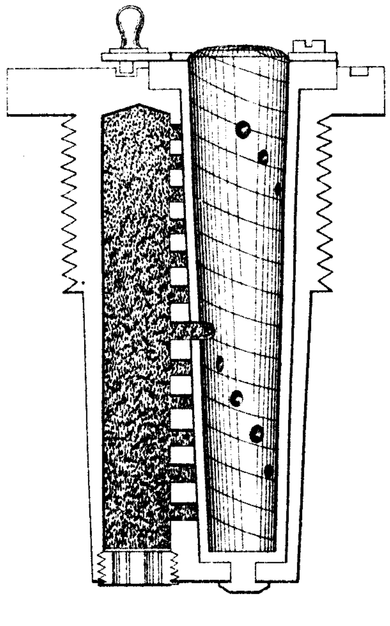


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Figure IV., Plate XXVI., illustrates a percussion-fuze which it is believed might prove very efficient. F is the usual fuze-stock, screwed into the head of a projectile, A; *P* is a plunger primed in a circle at *c*; *s* is a screw-plug furnished with two or more firing-pins, *n*; M is a magazine attached to the plunger by a ball-and-socket joint; *i* is a safety-wire, and *S* a safety-screw. The magazine is primed about its periphery, *p*, with fulminate, and is charged with fine powder.

The operation of this fuze is as follows: Before firing, the safety-screw, S, is withdrawn and thrown away. If the projectile strike point foremost, the plunger darts forward, and, exploding its priming, *c*, ignition is conveyed to the magazine, and thence to the charge through perforations in the bottom of the magazine, or by blowing off the bottom, which may be attached by crimping around the edge. If, however, the projectile fall on its side, the magazine, being only feebly restrained by the wire *i*, hinges about its socket-joint, and strikes with its primed periphery, *p*, the side of the fuze-stock at *p'*, thereby generating explosion. The safety-screw, *S*, when pressing tight against the flat end of the magazine, will keep the latter secure from motion during rough handling and transportation.

I have given as my opinion that the percussion-fuze should be employed much more generally than has hitherto been the case in our service, and that not only in shell but in shrapnel also it should be extensively used. There are circumstances, of course, when the use of a time-fuze becomes necessary in field projectiles. In a plunging fire from any considerable elevation, for example, the projectiles, if furnished with percussion-fuzes, may bury themselves out of harm's way in the ground before exploding; and in firing at such high angles of elevation that the projectile reaches the ground butt foremost, the time-fuze should of course be employed. But in ordinary field-firing I am convinced that the percussion-fuze will prove vastly more efficient than the best time-fuze, and it may be well to examine some of the reasons in detail for this belief.

A time-fuze should possess the following essential properties, else it cannot be considered efficient and successful:

1. Regularity of burning to within at least one-tenth of a second.
2. Not liable to premature explosion.
3. Not liable to deterioration in store, handling, or transportation.
4. Not likely to be injured from shock of discharge.
5. Readily cut or adjusted.
6. Not dangerous to handle.
7. Not complicated or expensive.

If it is conceded that the time-shell or shrapnel, in order to be efficient, should explode within 100 feet of the enemy's front, then it is necessary that the fuze should burn, as cut, to within 1-10th of a second. In point of fact, however, I do not believe any time-fuze was ever made of which a majority would burn to within a full second of the time calculated for even moderate ranges—I mean, of course, in a practical firing test—and not burning calmly and quietly, without the disorganizing shock of discharge and powerful air-currents which affect the fuze in actual service. Now, in field-service, if we suppose the terminal velocity of the projectile to be 900 feet per second, it follows that if the fuze burn one second "short," the shell will explode some 900 feet in *front* of the object aimed at; and if the fuze burn one second "long," the explosion will occur nearly 900 feet *beyond* the enemy; while the variation either way of but half a second causes explosion either harmlessly beyond the enemy, or, with scarcely more effect, 400 feet in front of the correct bursting-point. At short ranges the error of burning is less, but the velocity of the projectile is greater.

In Figure I., Plate XXVII., let us suppose the projectile to have a velocity of 1,000 feet per second, and we will assume that the fuze is correctly cut or adjusted for the distance to the object, T. If the fuze burn correctly to within one-tenth of a second, the projectile will explode within 100 feet of the object, and, if in *front* of it, may prove effective. In good fuzes, probably one in twenty may cause explosion within this desired limit. The effect of explosion, however, is usually not formidable; the "cone of dispersion" flares widely; many fragments strike the ground at such an angle in front of the object that they do no harm and cannot ricochet; others fly up in the air and fall harmlessly beyond the object; and I have known a target ten by fifty feet escape without a fragment from a 30-pound shell exploded by a time-fuze within 100 feet of it. If the fuze burn one-tenth of a second *long*, explosion occurs, of course, *behind* the object; and for every tenth of a second *short*, the projectile explodes 100 feet farther short of the object, and the dispersion of fragments becomes more and more wide and harmless in a rapid ratio. I repeat that, owing to the difficulties of service, but little dependence can be placed upon the regularity of time-fuzes, and that for ordinary ranges a large proportion do not burn true to within a whole second. Not too efficient when perfect, they are practically worthless when defective, and may indeed only serve to encourage the approach of the enemy. Another important objection to the time-fuze in field-service is that it is impossible to rectify the aim by the explosions. To an observer stationed with the battery, all the shell may appear to explode admirably, when in fact some are exploding beyond and others hundreds of feet in front

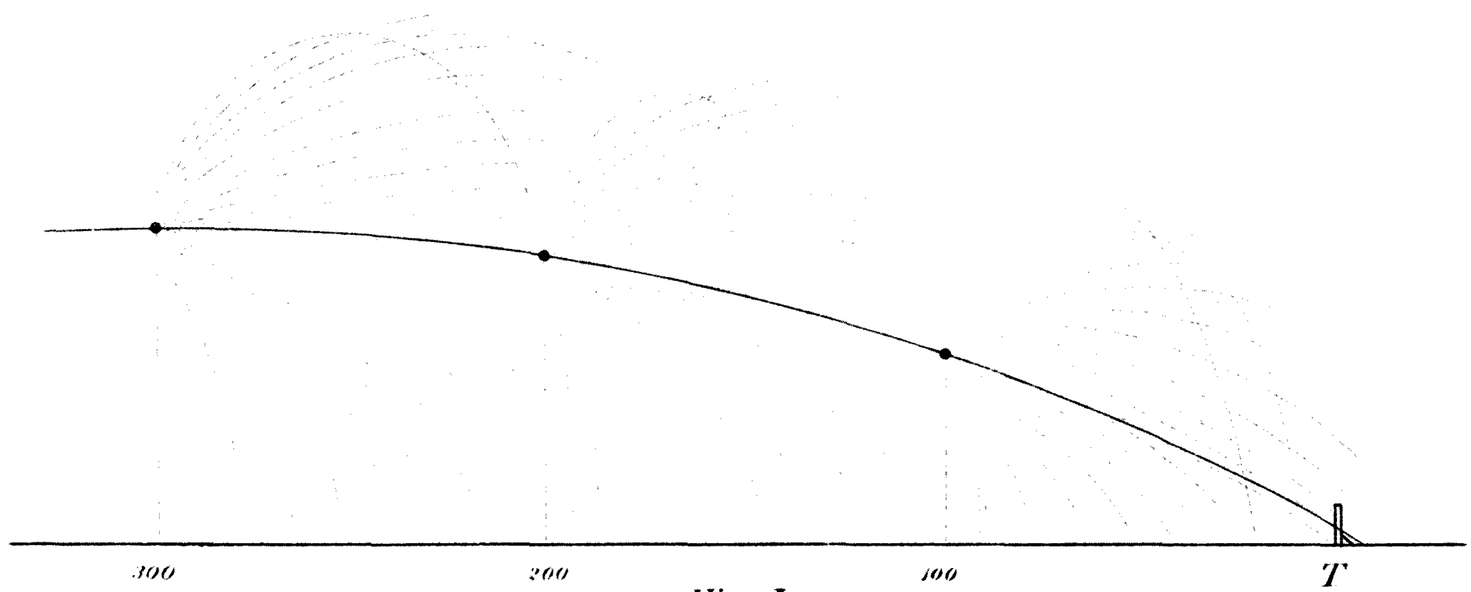


Fig. I.

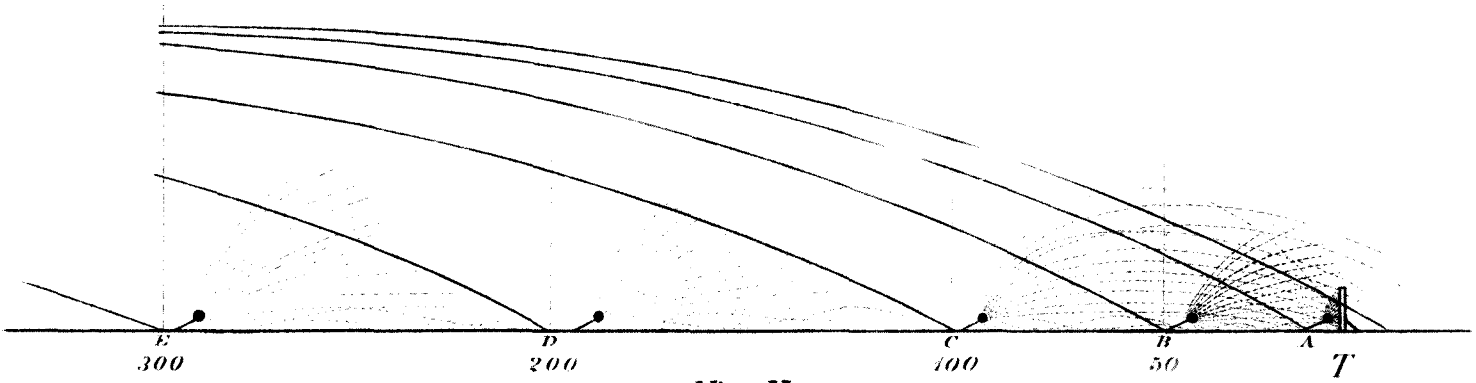


Fig. II.

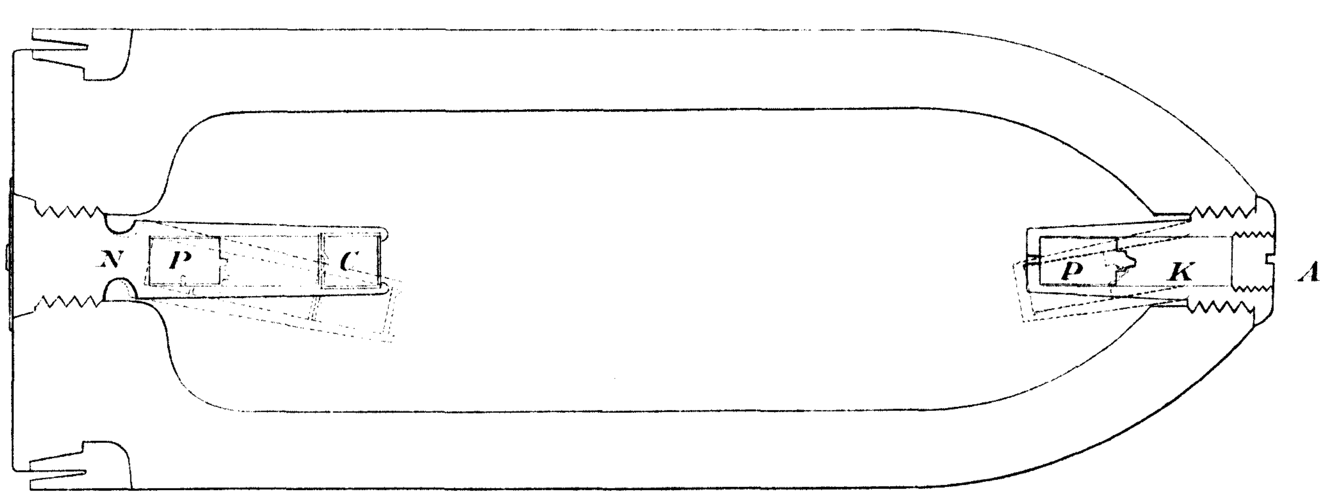


Fig. III.

of the enemy. I have frequently observed batteries in action, and even in target-firing, when those serving the battery imagined they were doing unexceptionably fine shooting; whereas, from my position on the flank, I would observe that not one shell in twenty exploded at the correct point. I feel confident that hundreds of officers have had a similar experience.

The percussion-fuze in this last respect possesses a great advantage over the time-fuze, for every projectile which explodes indicates, as perfectly as any "marker" could do, the exact range, deviation, etc., of the firing, which can accordingly be at once corrected.

Referring to Fig. II., Plate XXVII., we may examine the usual action of the percussion-fuze in field-firing. When the projectile strikes the ground, it takes some time for the fuze to communicate explosion, which accordingly does not occur until the projectile has left the ground, and is rising therefrom, usually from five to seven feet from the point of impact, and from one to two feet above the surface. This statement may be easily verified by firing percussion-shells over a level stretch of ground or along a sandy beach; at the extremity of the range in each instance will be found two marks, the first being the clean, fresh graze of the projectile, and the second the point of explosion, sometimes powder-stained.

If we suppose the piece to be so correctly aimed that the projectile passes through the object, T, the explosion will occur behind the object, but we have at least the effect of direct impact. Next, supposing the projectile to strike within fifty feet of the object; nearly all the fragments will be caught by a target 10 × 20 feet, and, in case of non-explosion, the projectile will strike by ricochet. At one hundred feet distance, the explosion will still be deadly, and the ricochet, in case of non-explosion, still dangerous. Many of the fragments which strike the ground do so at such an angle as to ricochet and be capable of execution. I have little doubt that greater effect would be produced by explosions caused by a percussion-fuze at three hundred feet, than by those of the time-fuze at one hundred feet from the object aimed at; and when it is considered that a great proportion of the percussion-fuzes may be exploded, at fair ranges, within one hundred feet, while the majority of time-fuzes will fail to operate within four or five times that distance, I think it cannot be doubted that the percussion-fuze will generally prove by far the more efficient of the two.

The combination-fuze I have a poor opinion of. Besides being generally more or less complicated, it is usually not equal, as a time or percussion fuze, to the more simple forms of either kind. When the time arrangement fails to ignite or burns too long, the percussion arrangement will come into operation,

but in all likelihood in an unfavorable position; and whenever the time-fuze burns *short*, the shot will be lost. An efficient and cheap combination-fuze would prove of value, provided either the time or percussion arrangement could be used, and the plan was simple and easily understood by the soldier. It might be a good plan to attach a percussion-fuze to the base of a projectile, and the simplest and best form of time-fuze to the head; but it is best, in my judgment, to apply the two kinds of fuzes to different projectiles, which could then be used as occasion demanded.

Without the slightest hesitation—believing it impossible to make a time-fuze which will burn accurately within the necessary limits to be efficient—I venture the assertion that our shell and shrapnel practice would be vastly benefited by the exclusive use of the percussion-fuze and the *absolute suppression* of time-fuzes, instead of restricting the former to fifty per cent. of the shell alone employed; but as there will always occur during a campaign circumstances when a time-fuze should be employed, the efficiency of the service would probably be promoted by retaining a limited number of time-fuzes in the complement for every battery.

I am led to the foregoing opinions from personal observation of considerable practice in this country, and from the fact that the time-fuze is passing somewhat into disuse in Europe.

I therefore respectfully recommend that, while testing the merits of the pattern of case-shot on Plate III., we at the same time test the merits of the different kinds of percussion-fuzes herein described, and such others as may be presented, and, having determined upon the most efficient form, continue the experiment with case-shot, in order to definitely determine the relative merits of time and percussion fuzes for case-shot firing from rifled guns.

Fig. I.

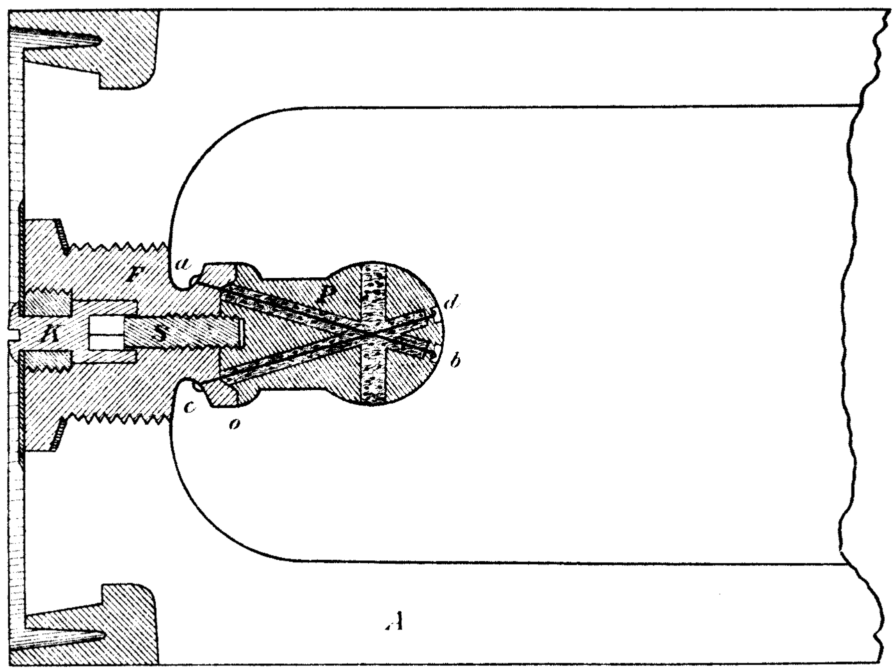
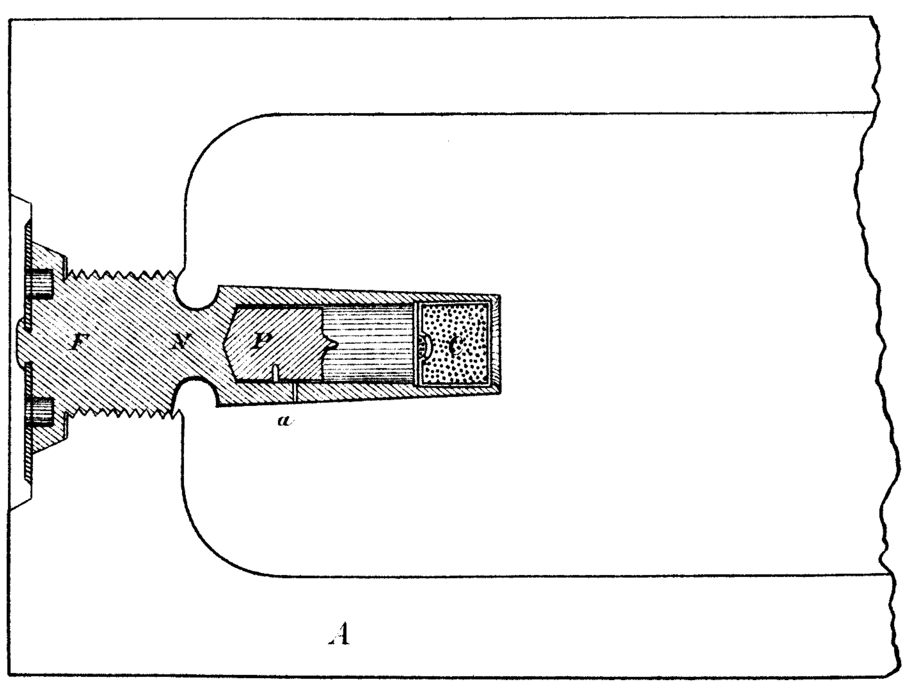


Fig. II.



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ADDENDA TO PART FIRST.

LETTER TO THE CHIEF OF ORDNANCE, NOVEMBER, 1873.

Referring to my report and recommendations on the subject of projectiles and rifling, it may not be uninteresting to recapitulate, in brief, the record of the new projectile which, for the last two years, has been in use by the Department for general experimental purposes. I therefore respectfully submit the following additional data and remarks, with the request that they be merged in my previous report.

Recent experiments at Fort Monroe Arsenal complete a record of over three hundred rounds with the new shot—a record which is unblemished by a single failure in any respect, and which comprises a great variety of calibres and weights; while the charges used were frequently heavier than had ever before been attempted in this country. Thus, 3-inch projectiles of 9, 10, 11, 12, and 12½ lbs.; 8-inch of 150, 170, and 190 lbs.; 10-inch of 250, 300, 330, 390, and 400 lbs.; and 12-inch of 600, 650, and 700 lbs., have been fired with heavy charges, and all with never-failing satisfaction and accuracy, and with infallible smoothness of flight. The following table gives a summary of a few of the results obtained, in some cases taking the average of a series.

Referring to the reports of Colonel Baylor, from which the extracts in Table XIII. have been made, it will be found that in all cases where a series of rounds have been fired with these projectiles and an unvarying charge, the resulting pressures, velocities, and ranges have been marked by a great degree of uniformity, while even with inferior powder we encounter none of those "anomalous" results of enormous pressures and reduced or disproportionate velocities so often traceable to misconduct on the part of the projectile. The projectile, thus acting uniformly under all circumstances, affords a fair opportunity of testing our experimental powders; and accordingly the wisdom of the Department in selecting this projectile for such purpose is abundantly vindicated.

TABLE XIII.

A brief Summary of Results obtained up to November 1, 1873, with the New Projectile and Experimental Powders. From Reports of Major and Brevet-Col. T. G. Baylor, Commanding Fort Monroe Arsenal.

Date.	Calibre of Gun.	Projectile.		Powder.		Pressure per sqr. inch.	Average Muzzle Velocity.	Action of Projectile.
		Kind.	Weight.	Kind.	Weight.			
	Inches.		Pounds.		Pounds.	Pounds.	Feet.	
April, 1871	3	Shell	9.2	Old Mortar	1		1236	Perfect.
August, 1872	3	"	9.4	" "	1		1208	"
	3	"	10	New "	$1\frac{1}{4}$		1346	"
	3	"	10	" "	$1\frac{1}{2}$		1450	* "
Dec., 1872	3	"	9.2	Old "	3		1711	"
June, 1872	8	"	140	Old Mam.	20	21,000	1352	"
Oct., 1872	8	Cored Shot	167	"	22	25,000	1310	"
Feb'y, 1873	8	" "	190	"	30	50,000	1352	"
March, 1873	8	" "	170	Hexagonal	35	30,000	1481	"
April, 1873	10	Shell	330	"	50	22,000	1350	"
" "	10	"	330	"	60	26,000	1420	"
" "	10	Cored Shot	387	"	60	28,000	1352	"
" "	10	" "	400	"	70	35,000	1365	"
Jan'y, 1873	10	" "	400	Cake	69	24,000	1372	"
" "	10	" "	400	"	79	38,000	1468	"
" "	10	Shell	253	Hexagonal	50	20,000	1540	"
Oct., 1873	12	Cored Shot	600	"	90	24,000	1275	"
" "	12	" "	600	"	100	26,000	1316	"
" "	12	" "	600	"	110	37,000	1375	"
" "	12	" "	700	"	90	28,000	1200	"
" "	12	" "	700	"	100	38,000	1280	"

* The three last charges and velocities given in Table II., Part First, were erroneously recopied from a subsequent record. They should read as follows: $1\frac{1}{4}$ pounds, 1,274 feet; $1\frac{1}{2}$ pounds, 1,308 feet; 3 pounds, 1,711 feet.

The important improvements recently made in our powder, and the unquestionably fine results already obtained, indicate that notwithstanding our enforced inaction during the past five years, so pregnant with improvements in this direction in the Old World, only a slight effort is required to place ourselves again in the van on the question of effective heavy ordnance and efficient powder and projectiles.* A few years ago we led all nations in the size and destructive

* We are very prone, I think, to overestimate the strength of foreign armaments, from the fact that the introduction of every new gun is heralded with *élan*, and we are familiarized with the wonders expected of it long before it has left the workshop. We lose sight of the time necessary to reproduce even a few guns of such pattern, and the delays occasioned by changes of plan, trials, proofs, etc., and innocently suppose that the fortifications and ships of our neighbors must be bristling with guns of the formidable character of which we have been reading for a year or two. I have not the slightest doubt, for example, that

power of our guns, in the strength of our cast-iron projectiles, and in the quality of our powder. Since then other Governments have taken up these various subjects at points where we were compelled by an economical Congress to leave them off. England has produced her 35-ton gun and pellet and pebble powder; while Krupp, in Prussia, adopting Rodman's prismatic powder, has developed a velocity of 1,500 feet in a 12-inch rifle. This last feat of Krupp we may never be able to excel, but may practically equal in our simpler and cheaper muzzle-loading system; while, by a simple increase of calibre in our guns, we may meet any demand for increased power.

In Ordnance Notes No. III. were recorded the results of experiments with "hexagonal" powder up to May 3 in the 15-inch smooth-bore. Subsequent tests indicate that it is admirably adapted for use in heavy rifles.

Table XIV. is compiled from the original reports of Colonel Baylor, and comprises the latest firing with 8-inch, 10-inch, and 12-inch rifles.

During the progress of experiments with cake-powder a vent was bored in the breech of the 10-inch Rodman rifle in prolongation of the axis of the bore. The first three charges of hexagonal powder were ignited through this vent, and it will be interesting to compare the results with the subsequent rounds, where the ordinary vent was used. Referring to rounds Nos. 48 and 50, it will be seen that, weight for weight of powder and projectile, equal velocities were attained, while the use of the experimental vent involved more than double the pressure; and referring to round No. 51, it is seen that the addition of ten pounds to the charge imparts an additional velocity of about seventy feet when fired by the ordinary vent, while the pressure is still less than half that resulting from the use of the experimental vent and the lighter charge.

The density of sample "E. V." hexagonal powder is 1.755; that of "E. U." is 1.775. Sample E. V. proving very superior in the 15-inch gun, it may be in-

a great majority of officers, of both the Army and Navy, and the great mass of the public generally, believe that England has hundreds of built-up wrought-iron and steel Woolwich rifles of ten-inch, eleven-inch, and twelve-inch calibre; whereas her complement of such guns up to January, 1873, was, I believe, as follows:

Number of	10-inch Woolwich guns of 18 tons available, about	18.
"	11-inch Woolwich guns of 25 tons " "	8.
"	12-inch Woolwich guns of 25 tons " "	15.
"	12-inch Woolwich guns of 35 tons " "	2.
"	13-inch Elswick guns of 25 tons " "	1.

In addition to the above might be mentioned something under four hundred 9-inch rifles, and less than one hundred 8-inch rifles—altogether, scarcely a sufficient number to place one of our principal harbors in a respectable condition of defence.

Prussia, in the matter of heavy guns, is probably not so well off as England. Other countries are doubtless still further behind.

TABLE

Record of Firings at Fort Monroe Arsenal,

No. of Fire.	Date.	Kind of Cannon.	Powder.		Projectile.		Pressure, lbs. per sq. inch of bore.	Initial velocity, feet.	Elevation in degrees.
			Kind.	Weight	Kind.	Weight.			
	1873			*Lbs.*		*Lbs.*		*100 ft. from gun.*	
155	Feb. 18	8″ wrought-iron rifle	Old Mammoth	30	Butler..	190	38,000	1,286	$3\frac{1}{5}$
156	"	" "	" "	30	" ..	187	50,000	1,342	$3\frac{1}{5}$
157	"	" "	" "	30	" ..	190	69,000	1,342	$3\frac{1}{8}$
158	"	" "	" "	30	" ..	188	43,000	Not taken	$3\frac{1}{5}$
159	"	" "	" "	30	" ..	186	63,000	"	$3\frac{1}{5}$
160	"	" "	" "	30	" ..	187	48,000	"	$3\frac{1}{8}$
161	"	" "	" "	30	" ..	190	57,000	"	$3\frac{1}{8}$
162	"	" "	" "	30	" ..	189	44,000	"	$3\frac{1}{8}$
163	"	" "	" "	30	" ..	186	32,000	"	$3\frac{1}{8}$
164	"	" "	" "	30	" ..	191	61,000	"	$3\frac{1}{8}$
165	"	" "	" "	30	" ..	184	40,000	"	$3\frac{1}{8}$
166	"	" "	" "	30	" ..	190	76,000	"	$3\frac{1}{8}$
167	"	" "	" "	30	" ..	186	50,000	"	$3\frac{1}{8}$
169	Mar. 10	8″ wrought-iron rifle	Du Pont's hexagonal	35	Butler..	167	22,500	Lost.	$3\frac{1}{12}$
170	"	" "	" "	35	" ..	168	24,500	1,460	Doubtful.
171	"	" "	" "	35	" ..	168	29,500	1,475	..
172	"	" "	" "	35	" ..	167	29,500	1,485	3
173	"	" "	" "	35	" ..	168	28,500	1,460	3
174	"	" "	" "	35	" ..	168	37,000	Not taken	3
175	"	" "	" "	35	" ..	168	36,500	"	3
46	April 10	10″ Rodman rifle ...	Hexagonal "E. V."	50	Butler..	300	52,000 }	1,410	$\frac{1}{3}$
47	"	" " ...	Hexagonal "E. U."	50	" ..	300	36,000 }	1,410	$\frac{1}{3}$
48	"	" " ...	" "	50	" ..	330	57,000 }	1,341	$\frac{1}{3}$
49	"	" " ...	" "	50	" ..	330	22,000	Lost.	$\frac{1}{3}$
50	"	" " ...	" "	50	" ..	330	22,000	1,341	$\frac{1}{3}$
51	"	" " ...	" "	60	" ..	330	26,000	1,410	$\frac{1}{3}$
52	"	" " ...	" "	50	" ..	400	25,000	1,241	$\frac{1}{3}$
53	"	" " ...	" "	60	" ..	387	27,000	1,345	$\frac{1}{3}$
54	"	" " ...	" "	60	" ..	387	29,500	1,341	$\frac{1}{3}$
55	"	" " ...	" "	70	" ..	400	35,000	1,357	$\frac{1}{3}$
56	April 11	10″ Rodman rifle ...	Hexagonal "E. V."	40	Butler..	387	24,000	1,185	$\frac{1}{3}$
57	"	" "	" "	50	" ..	387	31,000	1,292	$\frac{1}{3}$
3	Sept. 4	12″ Rodman rifle ...	Hexagonal "F. E."	50	Butler..	600	22,000	1,056	0
4	"	" " ...	" "	60	" ..	600	24,000	1,130	$\frac{1}{6}$
5	"	" " ...	" "	70	" ..	600	25,000	1,187	$\frac{1}{3}$
6	"	" " ...	" "	70	" ..	600	23,000	1,182	$\frac{1}{3}$
7	"	" " ...	Square "F. D."	60	" ..	600	23,000	1,113	$\frac{1}{6}$
8	"	" " ...	" "	80	" ..	600	28,000	1,234	$\frac{1}{3}$
9	"	" " ...	" "	80	" ..	600	23,500	Lost.	$\frac{1}{2}$
10	Sept. 8	12″ Rodman rifle ...	Hexagonal "F. E."	80	Butler..	600	25,000	1,200	0
11	"	" " ...	" "	70	" ..	700	21,000	1,089	0
14	"	" " ...	" "	90	" ..	600	24,000	1,272	$\frac{1}{2}$
15	Oct. 1	12″ Rodman rifle ...	Square "F. D."	70	Butler..	700	23,000	Not taken	$\frac{1}{2}$
16	Oct. 22	12″ Rodman rifle ...	Hexagonal "F. P."	80	Butler..	600	18,000	1,188	$\frac{1}{4}$
17	"	" " ...	" "	90	" ..	600	24,000	1,269	$\frac{1}{4}$
18	"	" " ...	" "	100	" ..	600	26,000	1,310	$\frac{1}{3}$
19	"	" " ...	" "	110	" ..	600	37,000	1,368	$\frac{1}{2}$
20	"	" " ...	" "	110	" ..	600	37,000	1,364	$\frac{1}{2}$
21	"	" " ...	" "	100	" ..	650	33,000	1,266	$\frac{1}{3}$
22	Oct. 24	12″ Rodman rifle ...	Hexagonal "F. Q."	60	Butler..	600	25,000	1,102	$\frac{1}{2}$
23	"	" " ...	" "	70	" ..	600	27,000	1,154	$\frac{1}{3}$
24	"	" " ...	" "	90	" ..	600	28,000	1,260	$\frac{1}{4}$
27	"	" " ...	Hexagonal "F. P."	100	" ..	650	37,000	1,272	$\frac{1}{4}$
29	"	" " ...	" "	90	" ..	700	28,000	1,195	$\frac{1}{2}$
30	"	" " ...	" "	100	" ..	700	30,000	1,272	$\frac{1}{2}$

Five rounds omitted when other projectiles used.

XIV.

with Improved Powder and Projectiles.

Deviation, in feet and inches, from point aimed at.				Deviation, in feet and inches, from centre of impact.				Wind.	SPECIAL REMARKS ABOUT EACH FIRE, Such as sound of projectile in air—whether clear and smooth, irregular, wobbling or tumbling, stripping, scattering fragments, effect on piece, etc., etc., etc.
Right.	Left.	Above	Below.	Right.	Left.	Above.	Below	Strength and direction	
..	8' 5"	6' 6"	..	..	2' 5"	4' 4"	..	Front, left, and light	At target—clear, smooth sound.
..	3' 10"	0' 5"	..	2' 2"	..	..	1' 8"	“ “	“ “ “
..	9' 0"	5' 4"	..	..	3' 0"	3' 3"	..	“ “	“ “ “
..	6' 7"	6' 0"	..	..	0' 7"	3' 11"	..	“ “	“ “ “
..	4' 8"	8' 7"	..	1' 4"	..	6' 6"	..	“ “	“ “ “
..	5' 4"	..	1' 6"	0' 8"	..	..	3' 7"	“ “	“ “ “
..	5' 0"	2' 3"	..	1' 0"	..	0' 2"	..	“ “	“ “ “
..	6' 6"	..	4' 8"	..	0' 6"	..	6' 9"	“ “	“ “ “
..	6' 4"	0' 4"	..	..	0' 4"	..	1' 9"	“ “	“ “ “
..	4' 10"	0' 4"	..	1' 2"	..	..	1' 9"	“ “	“ “ “
..	8' 0"	6' 6"	..	..	2' 0"	4' 5"	..	“ “	“ “ “
..	6' 0"	..	3' 6"	0' 0"	0' 0"	..	5' 7"	“ “	“ “ “
..	3' 2"	0' 8"	..	2' 10"	..	..	1' 5"	“ “	“ “ “
2' 8"	..	9' 6"	..	..	..	..	..	Variable	At target—clear, smooth sound.
..	..	..	..	..	..	..	..	“	“ “ “
..	..	..	..	..	..	..	..	“	“ “ “
..	8' 0"	..	3' 6"	..	1' 11"	..	5' 3"	“	“ “ “
..	8' 2"	6' 0"	..	..	2' 1"	4' 2"	..	“	“ “ “
..	5' 4"	2' 8"	..	0' 9"	..	0' 10"	..	“	“ “ “
..	2' 10"	2' 0"	..	3' 3"	..	0' 3"	..	“	“ “ “
These three rounds were fired by means of a vent through the breech, in prolongation of axis of bore.								....	At butt—sabot took grooves well.
								....	“ “ “
								....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ shot lost.
..	..	..	..	..	..	..	..	....	“ sabot took grooves well.
..	..	..	..	..	..	..	..	....	At butt—sabot took grooves well.
..	..	..	..	..	..	..	..	....	“ shot lost.
..	..	..	..	..	..	..	..	....	At butt—sabot took grooves well.
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	At butt—shot lost.
..	..	..	..	..	..	..	..	....	“ sabot took grooves well.
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	At butt—sabot took grooves well.
..	..	..	..	..	..	..	..	....	At butt—sabot took grooves well.
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	At butt—sabot took grooves well.
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “
..	..	..	..	..	..	..	..	....	“ “ “

ferred that a powder well adapted to the 15-inch smooth-bore is also well suited to the 10-inch rifle; but that where projectiles of unusual weight are used in the 10-inch rifle, a slight increase in the density of the powder will secure somewhat better results.

The first thirteen rounds recorded in the accompanying table were fired at a target 1,500 yards from the gun; they comprise all the heaviest (190-pounders) 8-inch projectiles on hand at the time. The place and date of manufacture of the powder employed are not definitely known; it was made during the Rebellion, and of a lot shipped from several forts in New York Harbor. In view of the heavy charges and great weight of projectiles, the average pressure cannot be regarded as very high for powder of early manufacture. Some of the barrels had their contents considerably more affected by dampness than others, although the accuracy obtained, *i.e.*, the small *vertical* deviation, would indicate that the irregularities of pressure recorded might be in part attributable to the unsatisfactory action of the large internal pressure-gauge, which appeared to be ill adapted to the bore of the gun.

After the fifth of the above rounds, as the shot were clustering high (see target on Plate XXIX.), the gun was lowered about five feet on the target, thus practically making two target-records, and necessarily increasing the mean vertical deviation. Had the aim not been thus lowered on the target, one shot would have gone over, and the target would have appeared as shown on the right, where the two groups are assembled.

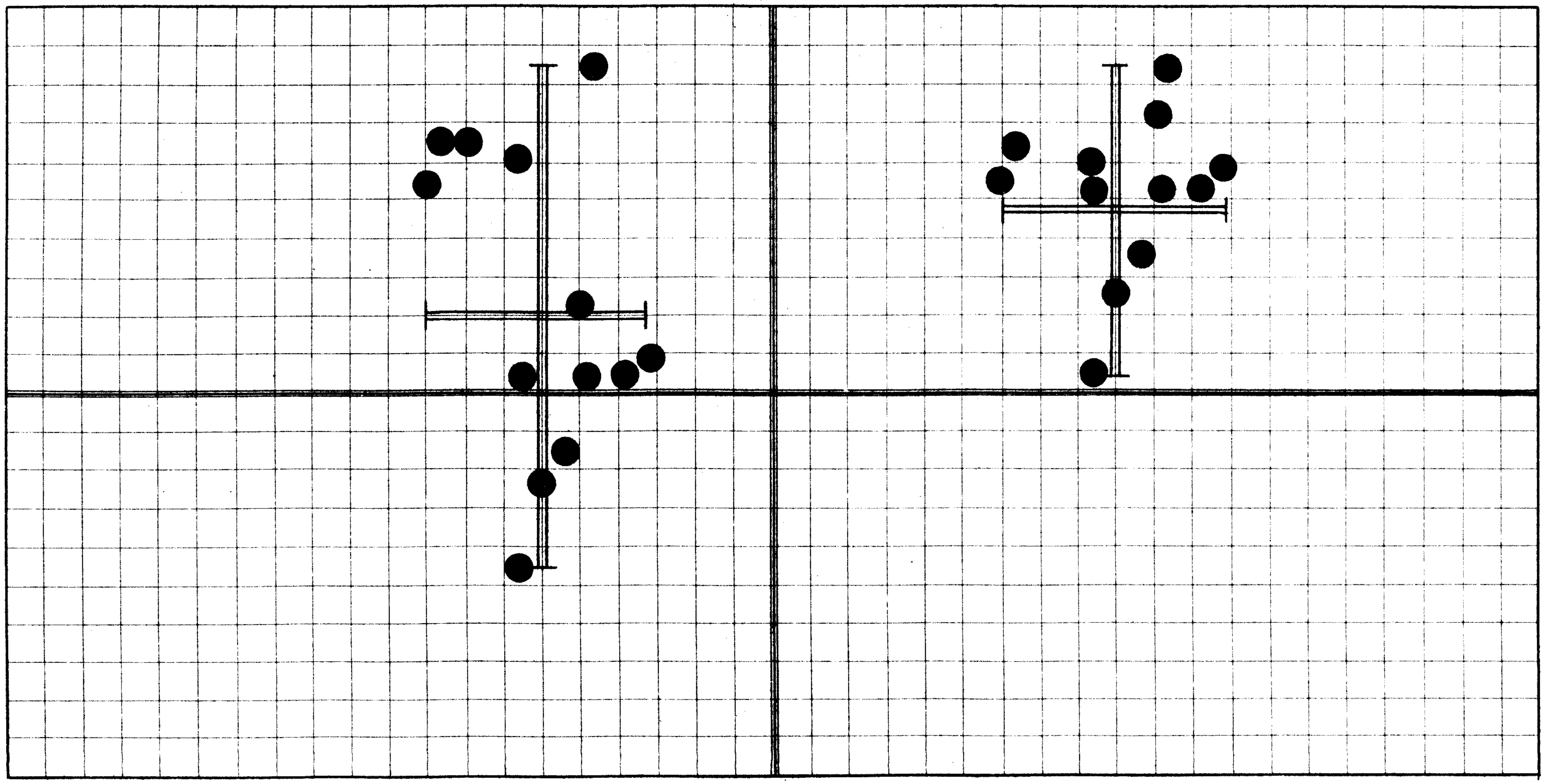
From round No. 169 to No. 175 inclusive, heavy charges of hexagonal powder, and projectiles of about 170 pounds, gave the admirable results (low pressures and high velocities) found recorded in the table. These rounds also were fired at the 1,500-yard target; but, owing to an error in sighting, three shots were expended, two being lost in getting the correct range and direction of the target. Of the remainder, the mean vertical, mean horizontal, and mean deviations from the centre of impact are 2′ 8″, 2′ 0″, and 3′ 4″ respectively. The projectiles were not perfect castings, the core being out of centre and causing a slight eccentricity.

After round No. 168, a smaller internal pressure-gauge was substituted for the large one previously used, and also an external gauge applied, the vent for which intersected the cartridge about midway. The pressures in the table represent, for each round, the average records of the two gauges. The average pressure with the internal gauge was 27,000 pounds per square inch; the mean variation from this average was 3,000 pounds; and the greatest variation 6,000 pounds. With the external gauge the average pressure was 32,000

8 Inch Rifle

Record of Target Firing at Fort Monroe Arsenal Feb. 18th 1873

Distance, 1500. Yards. Projectile 190 lbs. Charge 30 lbs.



Mean Vert. Dev. from Center of Impact	*3 ft. 5 in.*	*Mean Vert. Dev. from Center of Impact*	*2 ft. 2 in.*
Mean Hor. Dev. " " " "	*1 ft. 4 in.*	*Mean Hor. Dev. " " " "*	*1 ft. 5 in.*
Mean Deviation " " " "	*3 ft. 7 in.*	*Mean Deviation " " " "*	*2 ft. 6 in.*

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pounds; the mean variation 7,000 pounds; and the greatest variation 13,000 pounds.

The heavy wooden platform upon which the 10-inch rifle was mounted was uninjured; the light but strong wooden platform of the 8-inch rifle was lifted bodily out of the sand—at the front about 8 inches, and at the rear 3 inches—during twenty-two rounds. The appliances for sighting the gun were poor; wooden quoins and blocks of wood were used in place of an elevating screw. It is my belief that with good sights and elevating apparatus, well-made, concentric projectiles, and a level platform, the target-record here given, good as it is, can nevertheless be excelled.

I had the honor some months since of addressing to you certain objections to the employment of 10-inch cast-iron shot of 400 pounds. I not only deemed such weight excessive, but feared especially to employ it in the particular shot in question, as we knew nothing of the quality of the iron; and I pointed out the liability of a projectile of such length and weight crushing or breaking in the bore of the gun, if the grade of the iron happened to be poor or the casting defective.

The first lot of these projectiles was fired (some of them several times) with entire satisfaction; but a second lot from the same foundry proved not so fortunate. Out of eleven fired, six were recovered, and two of these were found to have been literally crushed from their own inertia, swelling out and *embedding their iron walls deeply into the rifling of the gun*, and causing a crack in the chamber. One of these projectiles showed thirteen and the other fourteen longitudinal cracks, extending throughout the cylindrical portion, and terminating at or near the junction of the sabot with the iron.* The powerful grip of the sabot, added to the pressure of nearly a million pounds upon the lower lip, acted as a reinforce to the projectile, and doubtless prevented it from crushing up completely within the bore. It is impossible to say how seriously the gun may have been injured by these two projectiles (and there may have been others which acted in the same way, as a number of shot which were fired upon this occasion could not be recovered for examination); although I think, from the nature of the crack—which extends from the vent to near the bottom of the bore—that the gun may be regarded as practically destroyed. Specimens extracted from this lot of projectiles, all of which proved to be very unsound, I have tested with the following results:

A. From broken shot—Density, 7.127; Tenacity, 13,600 pounds.

B. From unbroken shot—Density, 7.114; Tenacity, 14,266 pounds.

* These were cored shot brought up to weight by filling from the rear with about 5 pounds of sand and 10 pounds of lead—not a safe plan.

Of course the slight superiority of the metal in the unbroken shot was not its salvation; it doubtless had less velocity imparted to it; but these tests—in connection with others from projectiles which had been subjected to high velocities and heavy strains—would indicate that if a 10-inch projectile of 400 pounds be a sound casting, a tensile strength of 20,000 pounds per square inch will ensure it fully against any accident of the kind described. There is no reason, however, why projectiles of large size should not give a tenacity of 25,000 pounds per square inch as a minimum; and I would respectfully suggest that the metal of all projectiles for the future, even though procured in small quantities, be tested according to such rules as the Department has seen fit to establish for 15-inch shot. It is not fair to the gun, nor to the projectile, to make the latter of chunks of rotten iron; and I feel that I am justified in asking that the iron bodies for such projectiles of the new pattern as may be in future desired (especially when they are intended to be of great weight) be of fair quality of metal and sound and suitable castings.

I am thus particular in noting these, the only two failures of the new shot on record, because, apart from the perfect fulfilment of the prediction respecting them made a year previously, the accident itself is of a somewhat interesting character and of some value as a precedent. I wished, also, to explain how clearly I was justified in calling the record of the projectile an unblemished one, as it was no fault of the *principle* of the shot that it failed upon the two occasions cited. Yet the very character of the two accidents, in a record of over three hundred rounds, serves admirably to illustrate one great virtue of the double-lipped ring; namely, it is practically a reinforce to the projectile, and one, too, of a very powerful kind. It is just possible that the 10-inch cast-iron rifle at Fort Monroe may owe its salvation to the fact that these projectiles were thus clamped tightly, and, preserving their general integrity of form, were forced out of the gun as a whole; but I fear that the gun is seriously injured.

I am, nevertheless, of the opinion that 400 pounds is an excessive weight for a 10-inch projectile, though not as unreasonable as 700 pounds for a 12-inch; and am satisfied that projectiles of the weight recommended in Table VIII. of my report may be impressed with velocities sufficient to enable them to equal in destructive power the heavier projectiles moving with less velocity; this without incurring increased powder-pressure, and all with much less risk to the gun. For example, suppose 100 pounds of powder would impart to a projectile of 700 pounds a velocity of 1,250 feet under a pressure of 35,000 pounds per square inch; it would probably require an increase of at least one-tenth of the charge behind a projectile of 600 pounds to obtain the same pres-

sure. This would probably lead to an increase of velocity of at least 100 feet per second, and we should have the following comparison :

Calibre of Gun.	Weight of Charge.	Weight of Projectile.	Pressure per Square Inch.	Velocity per Second.	Energy or Stored Work.	Penetration in Iron Plates.
Inches.	Pounds.	Pounds.	Pounds.	Feet.	Tons.	Inches.
12	100	700	35,000	1,250	6,888	13.00
12	110	600	35,000	1,350	6,888	13.00

If, therefore, the above relative pressures and velocities are correct (and experience would indicate that I am within the mark), we see that in the two cases cited the stored energy is precisely the same. The slight advantage in penetration which the heavier shot would obtain at long ranges would not, in my judgment, compensate for the superior accuracy,* flatness of trajectory, and more direct impact of the lighter projectile, within ordinary ranges, apart from the fact that the latter is less liable to failure than the heavy shot, and consequently less liable to injure the gun. It would, in my opinion, be far wiser, if a projectile of 700 pounds must be fired, to increase the calibre of a 12-inch rifle three-quarters of an inch—to that extent weakening the gun—than to fire from a 12-inch bore so heavy a shot; simply because I deem 700 pounds a correct and safe weight to fire from a bore of 12.75 inches, and not so from a less calibre.

Table XV. furnishes some actual and a few estimated velocities of projectiles of various weights, and I think that an examination of it will tend to confirm the correctness of some of the views herein expressed.

The logarithmic curve on Plate XXX. is constructed from a formula for the penetration of iron plates deduced by Captain W. R. King from practical experiment, and which experience has proved to be nearly correct. In this curve the penetration in inches is the ordinate corresponding to an abscissa representing the number of foot-tons per inch of the shot's circumference deduced in the usual manner, namely, $\frac{w\,v^2}{2\,g} \div (2\,\pi\,R \times 2240)$. The parabolic curve in dotted line is constructed from the empirical formula of Captain W. A. Noble, R.A. These curves may be convenient for future reference; probably the former may be regarded as correct for unbacked and the latter for well-backed armor-plates.

By an inspection of the following table it will be seen that, notwithstanding

* Mainly, perhaps, through greater uniformity in the action of the projectile.

the limited nature of our experiments as recently resumed, we have already obtained from our cast-iron rifle of 23 tons results almost as formidable as have been obtained in England with the "35-ton" gun of wrought iron and steel, and results surpassing those of the "25-ton" English gun. This, too, with a powder-pressure probably averaging two-thirds that of the English. But there is no

TABLE XV.

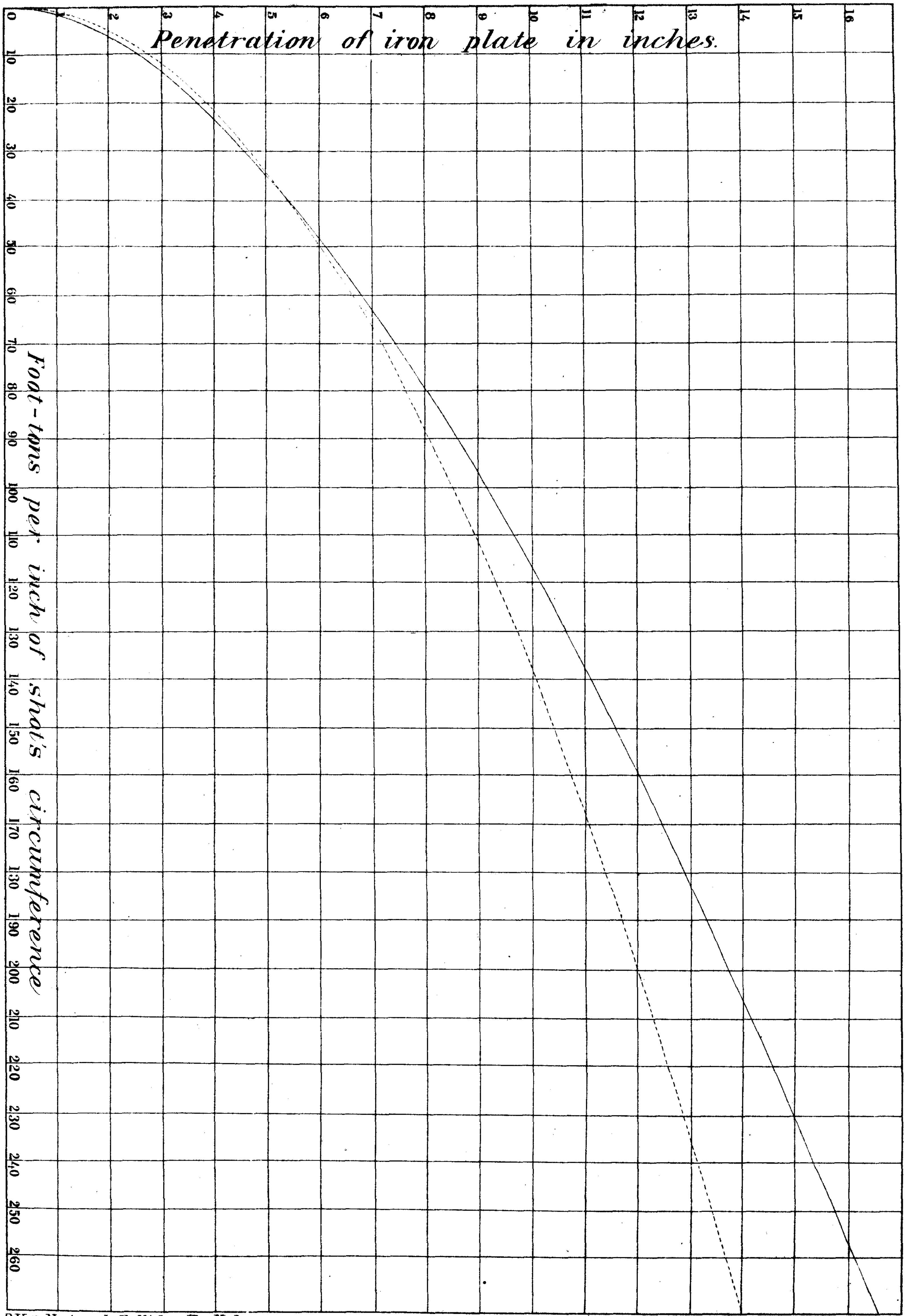
Comparative Energy and Penetration in Iron Plates of Projectiles of various Weights and Calibre.

Gun.	Weight of Charge.	Weight of Projectile.	Pressure per Sq. Inch.	Velocity at Muzzle.	Total Energy.	Per Inch of Shot Circum.	Penetration of Iron Plates.	Remarks.
	Lbs.	Lbs.	Lbs.	Feet.	Foot Tons.	Ft. t's.	Inches.	
U. S. 20-in. S. B. 51 tons.	200	1,080	20,000	1,500	16,845	271	16.50	....
U. S. 15-in. S. B. 22 tons.	100	454	25,000	1,600	8,056	174	12.60	....
U. S. 15-in. Rifle. 53 tons.	175	1,180	26,000	*1,330	14.471	310	18.00	Proposed.
U. S. 14-in. Rifle. 45 tons.	150	960	28,000	*1,350	12,059	278	16.75	Proposed.
U. S. 13-in. Rifle. 38 tons.	130	770	30,000	*1,380	10,165	251	15.80	Proposed.
U. S. 12-in. Rifle. 33 tons.	120	600	40,000	*1,475	9,049	241	15.40	Proposed.
U. S. 12-in. Rifle. 23 tons.	110	600	37,000	1,375	7,863	210	14.10	Hexagonal powder.
U. S. 12-in. Rifle. 23 tons.	100	700	38,000	1,280	7,955	213	14.25	Hexagonal powder.
Eng. 12-in. Rifle. 35 tons.	110	700	70,000	1,300	8,200	219	14.50	30 to 60 tons pres.
Eng. 12-in. Rifle. 25 tons.	85	600	60,000	1,300	7,030	188	13.20	Pressures variable.
Eng. 12-in. Rifle. 25 tons.	68	600	50,000	1,215	6,131	164	12.20	Pressures variable.
Eng. 11-in. Rifle. 25 tons.	85	535	....	1,315	6,415	187	13.20	Pressures variable.
U. S. 11-in. Rifle. 25 tons.	100	460	40,000	*1,520	7,367	214	14.30	Proposed.
Eng. 10-in. Rifle. 18 tons.	70	400	....	1,364	5,160	166	12.30	Pressures variable.
U. S. 10-in. Rifle. 18 tons.	70	400	35,000	1,364	5,145	165	12.20	Hexagonal powder.
U. S. 10-in. Rifle. 18 tons.	68	400	24,000	1,372	5,212	167	12.30	Perforated cake.
U. S. 10-in. Rifle. 18 tons.	78	400	33,000	1,451	5,830	187	13.20	Perforated cake.
U. S. 10-in. Rifle. 18 tons.	60	387	27,000	1,352	4,904	157	11.80	Hexagonal powder.
U. S. 10-in. Rifle. 18 tons.	60	330	26,000	1,420	4,612	148	11.50	Hexagonal powder.
U. S. 10-in. Rifle. 18 tons.	75	350	33,000	*1,520	5,606	179	12.90	Proposed.
Eng. 9-in. Rifle. 12 tons.	50	250	....	1,420	3,496	125	10.40	Pebble powder.
Eng. 8-in. Rifle. 9 tons.	35	180	32,000	1,413	2,492	100	9.15	Pebble powder.
U. S. 8-in. Rifle. 9 tons.	35	170	30,000	1,481	2,682	103	9.25	Hexagonal powder.
U. S. 8-in. Rifle. 9 tons.	35	180	33,000	*1,450	2,587	115	9.40	Hexagonal powder.
U. S. 8-in. Rifle. 9 tons.	40	180	38,000	*1,530	2,949	118	10.00	....

*The velocities marked thus * have been estimated, and it is thought that they may readily be obtained without a wide departure from the pressures set opposite them. All the other velocities have been obtained in practice. [See experiments at Fort Monroe, "English Text-Book on the Construction of Ordnance," and other sources.] The English continue to make improvements in their powder, but a vicious system of rifling prevents the attainment of high velocities, except at the sacrifice of an over-taxed gun, or, at best, of a scored and injured bore.

It is probable that the effect of the heavier projectiles upon iron targets would be greater than is here represented, as the racking effect of a tremendous blow would tend, in a degree, to assist penetration.

Plate XXX.



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doubt that our only 12-inch rifle is entirely too light for such work. Examining our 8-inch and 10-inch records, it will be seen that we are considerably in advance of England, and (as far as known) of other countries also. Our experiments have been limited, it is true, but I see no reason why results which have been obtained a dozen times may not be indefinitely repeated.

Krupp has one or two 12-inch rifles, and claims for them a velocity of 1,500 feet with projectiles of 664 lbs. and charges of 144 lbs. prismatic powder.* It is possible that the same charge of this kind of powder, if fired from one of our guns, would impart to a projectile of equal weight even greater velocity. To compete with this result, however, I would prefer a gun of 13-inch calibre, firing suitable weights of shot and powder; two of which on the English plan, or four on the Rodman system, could be produced for the cost of a single Krupp gun of 12-inch calibre.

Plate XXXI. shows the appearance of the new 12-inch projectile of 700 pounds as it comes from the gun. The perfect impression of the rifling upon the upper lip is scarcely exaggerated in the drawing.

Let us now examine how far the new projectile has fulfilled the numerous conditions imposed in the early part of my report of 1872:

1. *Superior Accuracy.*—It leaves little to be desired in this respect.

2. *Perfect Rotation, or "taking the grooves."*—It is absolutely infallible in this respect.

3. *Steadiness of flight.*—Without a single exception, every flight has been smooth and perfect.

4. *Absolute non-liability of the projectile to jam in the bore in loading or firing.*—Absolute immunity from this objection has been secured.

5. *Non-liability to strip, either in the gun or during flight.*—This has never been known to occur, although many of the tests have been severe. Indeed, stripping would seem almost impossible with this projectile.

6. *Must not injure the gun by breaking nor wedging.*—I believe that, weight for weight of the same metal, this projectile is the strongest known.

7. *Entire absence of balloting.*—There has never occurred any evidence of balloting by so much as the slightest unsteadiness of flight.

* In calculating, however, the stored energy of this projectile and its penetration in iron plates, we must (as Captain Von Doppelmair suggests), 1st, deduct from the total weight of the projectile the weight of the leaden jacket—in this case about sixty pounds—and, 2d, bear also in mind that "as the hole made by the shot in passing through the plate is only about as wide as the diameter of the shot, the lead jacket and bottom ring, which are of greater diameter, must naturally impede the projectile in piercing the plate. The correctness of the view set forth is confirmed by the partial disruption of the bottom ring, and the entire change and considerable heating of the lead-jacket on the passage of the shot through the plate."

8. *Maximum capacity for bursting charge.*—This condition is, of course, perfectly answered.

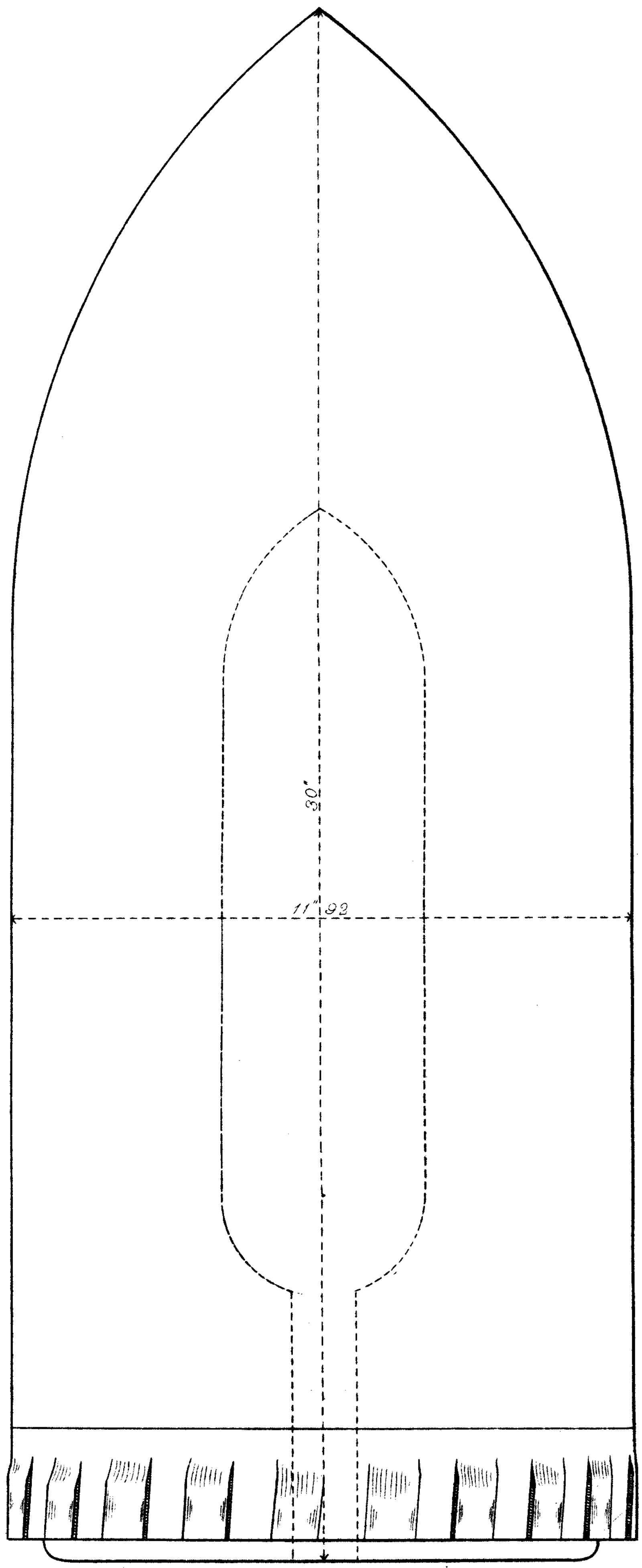
9. *Uniform and moderate pressures.*—The projectile having been used in experimenting with powder, heavy charges of various kinds have been employed, yet no pressure has ever been recorded so high that it could not be clearly attributable to the powder itself, or to some influence or circumstance apart from the projectile. Even in the case of the broken 10-inch shot previously referred to, the powder-pressures did not exceed 40,000 lbs. per square inch. No "anomalous" or unexplainable pressures have ever been obtained.

10. *Uniform and high velocities.*—The uniformity of velocities for equal charges of the same powder has been noticeable. While with equal weight of shot and the same powder there is scarcely a doubt that the expansive system yields the highest attainable velocities, the shot in question maintains a maximum or high rate in its own class.

11. *Uniform and good ranges.*—With uniform velocities the ranges will of course be uniform; with high velocities the ranges will be great; while the smoothness of the exterior of the shot gives the least possible atmospheric resistance. The record of the new projectile will show remarkable uniformity of ranges, even with indifferent powder.

12. *Absolutely safe to fire over the heads of our own troops—a contingency constantly arising in both land and sea-service.*—Shells may break from defects in the iron itself; they may burst prematurely by reason of a defective fuze; but fragments of shot, sabot, or studs should never leave the main body of the projectile from any defect in principle, weakness of construction, or absolute misconduct on the part of the projectile itself. A single stripping shot is more "demoralizing" when fired over the heads of our own troops than a hundred projectiles from the enemy; and scores of officers who served during the Rebellion will bear out this statement. I venture the assertion that there is less liability of the new projectile stripping or breaking than obtains in any other sabot, stud, or breech-loading projectile known.

13. *So strong and safe in principle as to allow a wide margin for all errors of manufacture, and even inferiority of materials.*—I repeat that I consider this projectile one of the strongest known; it is certainly stronger than the English shot—weakened as the latter is by stud-holes—or than the grooved shot, for the same reason; it is clearly stronger than the ordinary hard-ring or cup expansive projectiles, for reasons previously discussed at length; while it is probably somewhat stronger than the flanged or lead-coated projectile, because it is in a manner reinforced.



"Recovered" 12 in. Projectile of 700 lbs.

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14. *Non-liability to injury in store, handling, or transportation.*—The projectile under consideration does not require to be packed in shavings like the lead-coated, nor even handled as carefully as the stud projectile. Rifle projectiles are not usually handled roughly, but, on the contrary, with some care. The double-lipped ring, however, may be very badly bruised without in the slightest degree impairing its efficiency.

15. *Not too expensive.*—Deservedly a last consideration; for better a good shot, though an expensive one, than a poor one at half the cost. The new projectiles are not expensive, and with proper facilities they could be furnished at a reasonable cost and as cheaply as the English or Prussian projectile could be produced in this country with all necessary facilities for their manufacture. The South Boston Iron Company estimated for a large number of 300-pounder lead-sabot projectiles, and afterwards furnished to the Argentine Republic the double-lipped brass-sabot projectile instead, and without change of estimate.* The experimental projectiles, occasionally made in small quantities by Colonel Baylor, cost about ten cents per pound.

16. *Preservation of the bore.*—I should mention also—as a most important desideratum in any system of rifling and projectiles—the preservation of the bore in as perfect a condition as possible, by reducing the "scoring" action of the gas and the friction of the projectile to a minimum. From a careful consideration of all the circumstances bearing on this point, and an examination of the bores of guns from which these projectiles have been fired, I am convinced that the proposed system will be found to fulfil very perfectly this important condition.

I have also the satisfaction to state that the breech-loading projectile proposed by me in 1871, and illustrated on Plate XV., is behaving admirably in the Moffatt experimental field-gun. Few have as yet been fired, but they promise great accuracy, and possess superior capacity as field projectiles.

In conclusion, I consider that the perfect success of our new projectile, even with what is not deemed the most advantageous forms of rifling, adds force to the brief argument previously advanced in favor of fairly testing the merits of cast iron for heavy rifles by the construction of one of 13-inch or even

* "The Butler sabots, secured by dovetailing and leading, gave most satisfactory results, even under the enormously high pressures involved. There was no stripping, slipping, or breaking. In every case the sabot took the grooves with mathematical precision. With the 'double-lipped' sabot, the expanding system seems to have reached its ultimate limit of efficiency."—*Report of Captain Michaelis to the Chief of Ordnance, October 1st, 1873, on the inspection and proof of 10-inch Rodman rifles, manufactured by the South Boston Iron Company for the Argentine Republic, S. A.*

larger calibre and proper weight. Fired with a previously-determined *standard* charge of improved powder, and served with a projectile which may always be relied upon to behave uniformly and well, I would be much surprised if such a gun did not endure at least 500 rounds; and if two such guns could be constructed, one in the usual manner and the other with the core-barrel running entirely through the gun—afterwards closing the rear with a heavy V-thread breech-screw—great interest would be added to the experiment, and it can scarcely be doubted that valuable information would be obtained.

This method of casting the breech hollow, was proposed by Colonel Crispin last winter when arranging the details for the casting of the 9-inch Sutcliffe experimental breech-loading rifle, and was practically carried out in that gun.

On briefly reviewing some of the considerations involved, it will, I think, be acknowledged that there is a strong probability that, slight as it is, it may prove to be an important modification of the Rodman process. Referring to Fig. I., Plate XXXII., which represents a Rodman gun, it will be seen that the theories of the inventor relating to interior cooling and initial tension are practically carried out throughout the entire length of the *bore;* but that from the bottom of the bore to the base of the breech the circumstances of cooling and shrinkage are practically reversed, and that all the faults of a solid casting here obtain; and this, too, at the heaviest part of the gun. The consequence is that not only is the breech of the gun liable to be unsound at the centre, but there must be some neutral lines, more or less well defined, such as O N, along which the strains of shrinkage (of the solid and the hollow portions of the gun), diametrically opposite as they are, must intersect, constituting thereby planes of weakness—which, by the way, must nearly coincide with those produced by the intersection of the different systems of crystals whose principal faces are always found arranged in a position normal to the cooling surface.

Without attempting a rigid analysis of these conflicting strains, it may be well to illustrate them crudely as we know them necessarily to exist:

1. Treating of the hollow part of the casting, and considering it as made up of a number of concentric cylinders of little thickness. That cylinder or layer of metal next the bore is first cooled, and acquires a "set"; next, the succeeding layer is cooled, and in cooling shrinks and binds upon the first, and so on throughout the mass, the exterior of which is restrained as much as possible from too rapid cooling.

2. Consider now the breech or solid part of the gun. With the exception of a small portion in immediate contact with the end of the core-barrel, the exterior of the mass cools first, is greatly strained by shrinking upon the fluid and ex-

panded metal of the interior, and finally acquires a set; after which the inner layers in cooling shrink away from the more yielding portion of the mass (the fluid or semi-fluid interior), and hence there will obtain a mass of porous or open metal running through the breech in prolongation of the axis of the bore.

To this fact may be ascribed, I think, the frequent cracking at the bottom of the bore and vent, sometimes appearing early in the life of a gun, and which may ultimately lead to its destruction.

But the evil does not stop here. Suppose a ring, *a-b-c-d*, to be cut from the hollow portion of the breech, and another ring, *e-f-g-h*, from the solid portion; it will be found that the first ring cannot be cut through on one side before it springs open, rupturing a certain amount of metal in the effort, thus revealing an initial tension (in the direction of the arrows), which in a 15-inch gun or 12-inch rifle should be at least one-half the absolute strength of the metal, or say 15,000 lbs. per square inch on the exterior. On the other hand, if the solid disk, *e-f-g-h*, be first converted into a ring by boring, and be then cut through, it will probably be found to absolutely close up, to a limited extent (see arrows); and although we have never measured this force, the simple fact of its existence is all that is required for an argument; and the spectacle is presented of two enormous masses of metal, either contiguous or separated by very narrow neutral limits, the one mass strained powerfully in one direction, the other in an opposite direction; and occurring, as this does, at the very critical point of the termination of the bore (the point of operation of a severe transverse strain), it cannot but be very injurious in its effects.

It is the object of the proposed plan to avoid these conflicting strains; and this, it is thought, may be accomplished by allowing the core-barrel to pass entirely through the body of the gun, allowing a projecting mass of metal from the breech sufficient only for the accommodation of the core-barrel, and thick enough to furnish a bottom for the bore in cooling by water.

It is believed, however, that the improvement will not end here. As the bore will now extend throughout the entire length of the gun, the breech end must be closed; and by inserting a wrought-iron or steel breech-screw with a V or double V thread, and provided with a gas-check to cover the joint, a means will be furnished for a judicious distribution of the strains of discharge. In the case of the solid breech, for example, it is clear that there is no other than a longitudinal strain brought to bear upon it (if we except a compressive strain in prolongation of the bore, and a transverse strain along the line O N), and unfortunately both the longitudinal and transverse strains are operating more or less

directly through the lines of weakness previously described. Now, in the case of the hollow breech, supposing it to be closed by a V-thread breech-screw, as in Fig. II., Plate XXXII., the pressure of powder-gases upon the bottom of the bore (say 4,000,000 lbs.), instead of constituting altogether a longitudinal strain, is resolved into two components—by the medium of the inclined faces of the breech-screw—one of which remains longitudinal, while the other becomes tangential, which latter is just such a strain as the breech is well calculated to withstand; and by acting thus entirely in sympathy with the hollow portion of the gun, the transverse strain along O N is also reduced.

Experiments are about being set on foot having in view the practical elucidation of some of these important points, but, whatever the result of these experiments, I earnestly renew my recommendation that efforts be made to procure as speedily as possible a cast-iron rifle of large calibre constructed on the Rodman principle, believing that we now possess the means—through an unobjectionable system of projectiles and rifling and a good quality of powder—of subjecting such a gun to a fair trial, and that thus for the first time we shall be able to obtain a fair and crucial test of the merits of cast-iron for heavy rifled ordnance.

Fig. I.

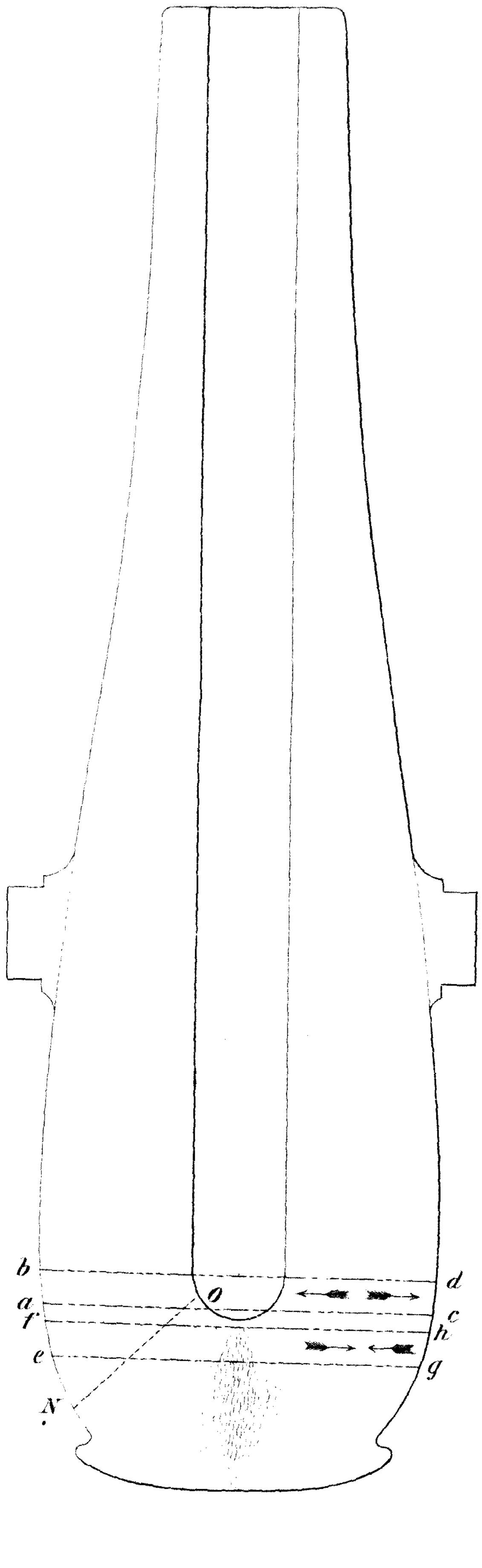
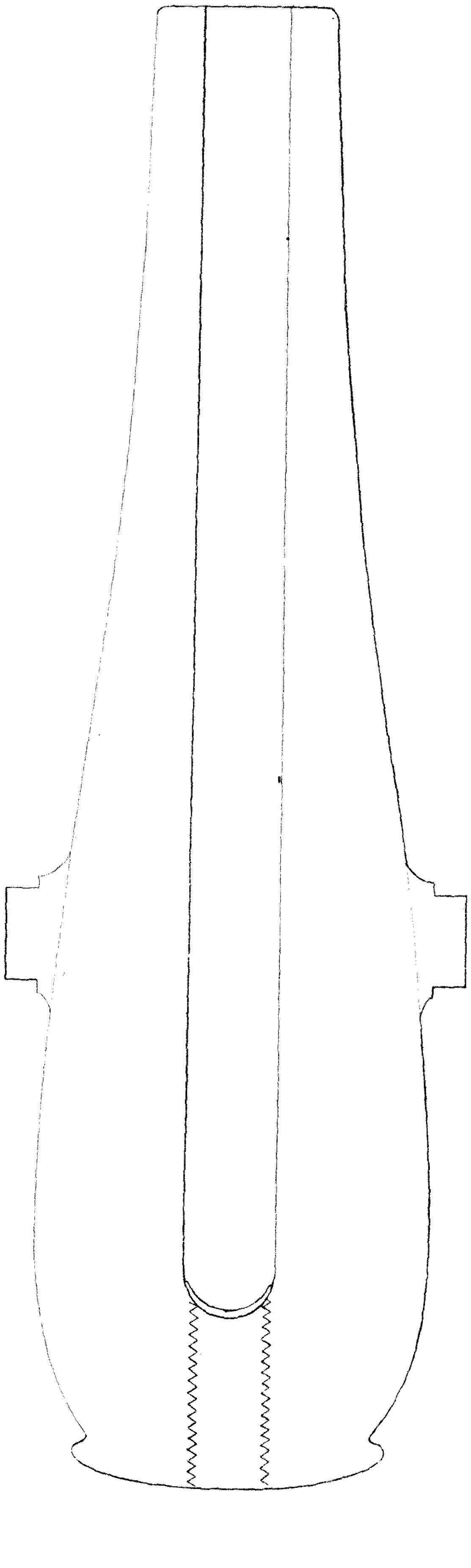
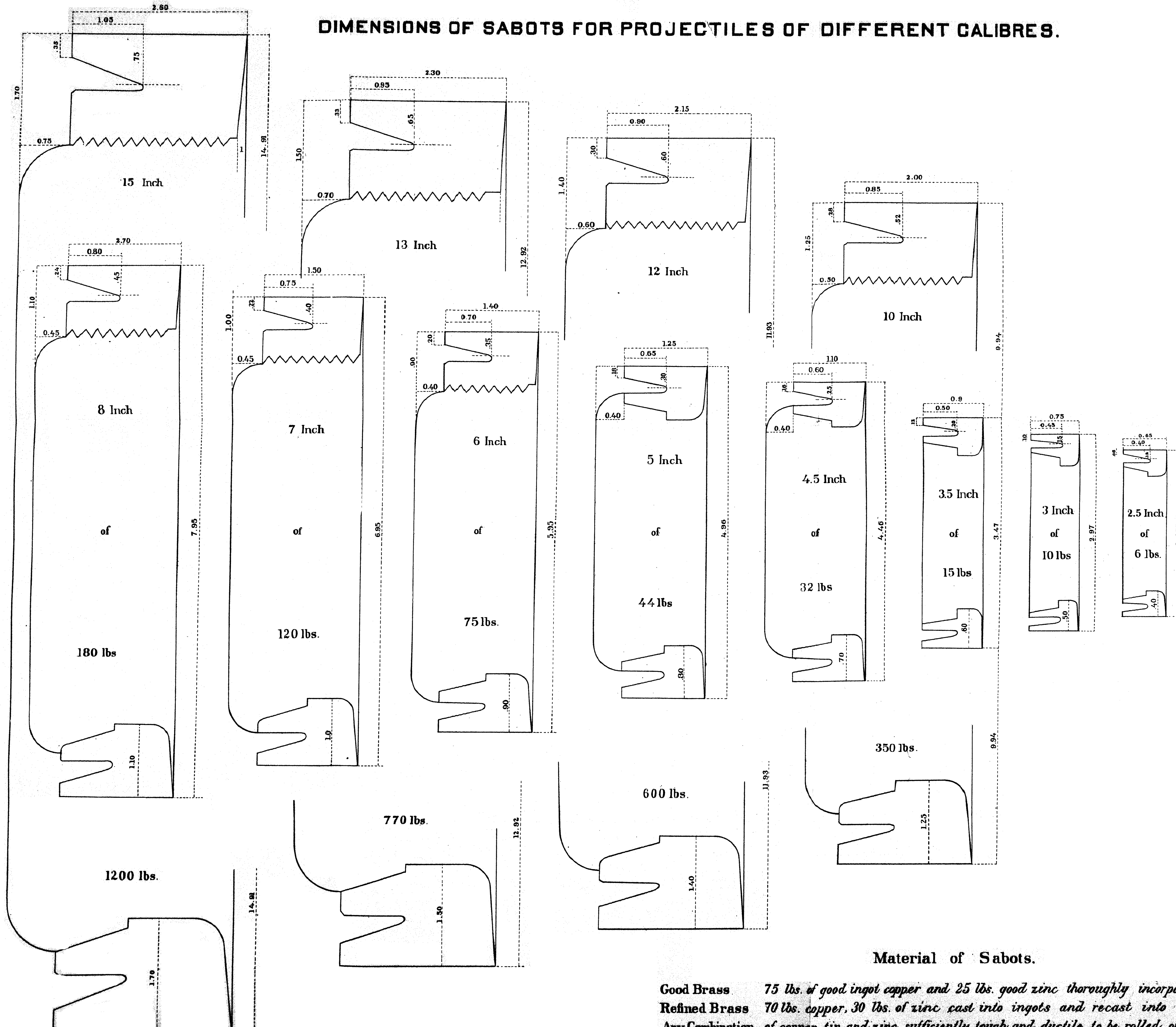


Fig. II.



D.Van Nostrand, Publisher, New York.

DIMENSIONS OF SABOTS FOR PROJECTILES OF DIFFERENT CALIBRES.



Material of Sabots.

Good Brass *75 lbs. of good ingot copper and 25 lbs. good zinc thoroughly incorporated, or*

Refined Brass *70 lbs. copper, 30 lbs. of zinc cast into ingots and recast into sabots, also*

Any Combination *of copper, tin and zinc sufficiently tough and ductile to be rolled or drawn.*

APPENDIX.

EXPERIMENTS AT SANDY HOOK, N. Y. H., WITH AN 8-INCH RIFLE CONVERTED, ON THE PALLISER PLAN, FROM A 10-INCH RODMAN SMOOTH-BORE GUN.—PRELIMINARY EXPERIMENTS DURING 1874.

An unavoidable delay in the publication of the foregoing report enables me to add brief mention of experiments with our expansive projectiles during the past few months, and of the satisfactory proof of an 8-inch rifle in which these projectiles were used.

The Ordnance Board of 1872 recommended that a number of experimental rifles of large calibre, both breech and muzzle loading, be procured and tested. Among these may be mentioned the following:

1. The Woodbridge muzzle-loading rifle, consisting of a steel tube wrapped with steel wire, trapezoidal in cross-section, and cemented or "brazed" in a bronze bath. The necessary "plant" for the construction of a 12-inch gun of this character has been completed, and it is expected that a 9-inch rifle will soon be in progress. The contemplated weight of the 12-inch gun is about 70,000 pounds.

2. The 12-inch Hitchcock muzzle-loading rifle, which is intended to be built up of wrought-iron disks, hollow, bevelled, and welded together. Preparations in progress. Contemplated weight, 70,000 pounds.

3. The 12-inch Thompson breech-loading rifle, having a cast-iron body, thin steel tube, and a rolling breech-block impinging against a cam. This gun will be finished in a few weeks, and will weigh about 80,000 pounds.

4. The 9-inch Sutcliffe breech-loading rifle, consisting of a cast-iron body, thick steel tube, steel breech-screw and eccentrically-pivoted breech-block. This gun is completed and is now undergoing trial. Its weight is 45,000 pounds, and it has been constructed with a view to increasing its calibre up to 10 inches, if deemed desirable.

5. Four muzzle-loading rifles, to be constructed from 10-inch Rodman smooth-bore guns, by the insertion of wrought-iron and steel tubes, on various accepted plans. Of these four guns, one 8-inch wrought-iron lined gun has been

finished and proved; one 9-inch gun, of similar construction, is finished and awaiting proof; and an 8-inch steel-lined gun has just been completed. The remaining gun will be steel-lined and of 9-inch calibre.

Pending the construction of these guns—in order that no unnecessary delay should be incurred—it was deemed important to settle upon the character of the powder to be used in their proof, and a series of experiments was accordingly instituted having in view the attainment of this end. Some years previously the Ordnance Department had fixed upon a standard of Mammoth powder, which was considered at the time to give satisfactory results; but the attention of Colonel Benét (now Chief of Ordnance) having been called to powder of regular polyhedral granulation, he was led to believe that the regularity of the grain (necessarily resulting in great uniformity of gravimetric density in the cartridges) would lead to uniformity of ignition, inflammation, and combustion, and that therefore improved results would probably mark the introduction of such a powder for use in our large guns. In the meantime, some extraordinary results had been obtained with perforated cake-powder, but its manufacture was attended with much difficulty and expense. It was generally considered that perforated hexagonal prisms would be the most practical form in which to use such powders. For the manufacture of this, however, no facilities were then at hand.* The introduction of powder of "hexagonal" granulation facilitated the solution of the problem, and the results obtained were considered so satisfactory as to lead to its adoption for the experimental rifles, and, in fact, for all our guns of large calibre.

These experiments with powder were conducted in the 15-inch smooth-bore gun, and in the 12-inch, 10-inch, and 8-inch rifles, and the result has been the selection of a powder which is considered well adapted to the 15-inch smooth-bore gun and to rifles of 8-inch, 9-inch, and 10-inch calibre. It is considered probable that rifles above a calibre of ten inches should employ a somewhat denser powder; so that before the proof of the experimental 12-inch rifles is commenced further tests of powder will probably be made. Many of the results of these experiments I have already given, but during the past few months some additional firing has occurred at Fort Monroe, chiefly with the 8-inch rifle. For the test of these experimental powders the new projectile has been exclusively employed; behaving (according to the reports of Colonel Baylor) with infallible uniformity, and giving entire satisfaction. The limited financial resources of the Department have restricted all these experiments to very narrow limits, and

* The Ordnance Department has now a press in operation, and is manufacturing a supply of perforated prismatic powder for experimental purposes.

no more firing has been done than was deemed absolutely necessary. It proved fortunate, indeed, that the experiments with powder were so quickly and satisfactorily settled, and that experiments with projectiles were not called for at all. It is worthy of remark that, since the first preliminary experiments with the 3-inch field gun, little opportunity has been afforded for experimenting with these projectiles, except such as was indirectly provided through these tests of powder. Changes of form, dimensions, and material were therefore made cautiously; and while some improvement has undoubtedly been effected, yet, from first to last, the projectiles have given never-failing satisfaction, and it is difficult to conceive wherein a greater degree of perfection is now to be attained. Experiments with the 8-inch rifle at Fort Monroe show that with charges of 35 pounds of Hexagonal powder, and projectiles of 170 pounds, an average muzzle velocity of 1,470 feet per second may be counted upon, and that with projectiles of 190 pounds and the same charge we may expect an average velocity of 1,420 feet.

The following are the results of two series of experiments with our new powder and projectiles:

TABLE XVI.

Extracts from Reports of Experimental Firing with different Lots of Hexagonal Powder from an 8-inch Rifle at Fort Monroe.

Date.	Calib'r of gun.	Powder.			Projectile.		Pressure per sqr. inch.	Velocity at muzzle.	Remarks.
		Kind.	Lot.	Wt.	Kind.	Wt.			
1874.	Inches.		F. U.	Lbs.		Lbs.	Lbs.	Feet.	Projectile.
March	8	Hexagonal	1	35	Butler	162	29,000	1,485	Took grooves well.
"	"	"	3	35	"	168	36,000	1,501	" " "
"	"	"	4	35	"	168	29,000	1,474	" " "
"	"	"	5	35	"	168	42,000	1,451	" " "
March	8	Hexagonal	2	35	Butler	190	40,000	1,356	Took grooves well.
"	"	"	6	35	"	190	45,000	1,423	" " "
"	"	"	7	35	"	190	39,000	1,407	" " "
August	8	Hexagonal	Dens. 1.750	35	Butler	190	28,000	1,442	Took grooves well.
"	"	"		35	"	192	30,000	1,434	" " "
"	"	"		35	"	191	24,000	1,424	" " "
"	"	"		35	"	195	47,000	1,426	" " "
"	"	"		35	"	192	23,000	1,393	" " "

A marked degree of uniformity has characterized the trial of each particular *lot* of powder, and the pressures and velocities have generally borne a proper correlation, the inconsistencies being so trifling as to be fairly considered accidental. Having determined by these tests the quality of each lot of powder, the manufacturer was apprised of the result, and requested to duplicate the particular lot selected. It was found that this powder could be more easily and exactly duplicated by the manufacturer than could the old style of mammoth granulation. In this manner, a satisfactory grade of powder having been determined upon, a quantity was procured for the proof of the experimental guns. The first few hundred barrels, manufactured in lots of fifty barrels each, have now been tested in the 8-inch converted rifle at Sandy Hook; and while all the powder must be regarded as good, and most of the lots are up to the standard, in two or three instances they fall a little short, so that out of the first thousand barrels there may be said to be about three grades of powder, with a difference in initial velocity between each grade of about 20 feet, or say 1,410, 1,430, and 1,450 feet for projectiles of 171 lbs. * It should be remarked that these velocities were obtained from a gun having a length of bore of only 14½ calibres, so that, when the gun was charged with 35 pounds of powder, the projectile had but five times its own length in front of the cartridge in which to accumulate velocity.

I have already alluded to the use of the projectile on Plate XV. in the Moffatt breech-loading field-gun, from which about one hundred and fifty rounds have now been fired, preliminary to its final test at Fort Monroe. This gun is rifled with the same number, width, and depth of grooves as the Krupp gun of similar calibre; the chamber is also the same, and, being adapted to the lead-coated shot, the front bearing band (S, S, Fig. I., Plate XV.) had to be shifted back so that the projectile would occupy no more than the proper space in the chamber. About one hundred of these projectiles have been fired, proving so superior to the lead-coated shot that Mr. Moffatt has decided to supply them for future use in this gun, discarding the lead-coated projectile altogether.

It was on account of this success that the system illustrated in Fig. II., Plate XIX., was adopted for a small experimental Sutcliffe breech-loader of 3.15-inch calibre. About one hundred of the projectiles shown in Fig. II. have been fired with such unvarying accuracy and good effect that the same system has been adopted by Mr. Moffatt for other experimental guns of his pattern now in progress.

The 12-inch Thompson breech-loading rifle will have the double chamber (Fig. II., Plate XVIII.), using a 600-lb. projectile, like that shown in Fig. I.,

* I except one lot, which fell a little short of 1,400 feet when fired during very damp weather.

Plate XIX., or on Plate XV. The bore, however, will be rifled with but seven grooves, the lands, or spaces between any two grooves, being wide enough to admit of two additional grooves being subsequently cut, thus making twenty-one in all. The experimental use of seven grooves is the suggestion of Mr. G. Leverich, Mr. Thompson's consulting engineer, who wishes, I believe, to make some practical experiments respecting the power required to rotate the projectiles by firing a few rounds before cutting the balance of the grooves. When all the grooves are cut, the rifling will resemble that given in Table X., except that there will be twenty-one grooves instead of twenty-five, and the pitch will be uniform instead of accelerating. This proposed preliminary experiment would, in my judgment, be more satisfactory; if the short-chambered system were employed, so that the front bearing band on the projectile could be dispensed with. With the short chamber and a moderately accelerating pitch, seven grooves might prove sufficient to rotate the shot, although in any event I consider that a more liberal gas-escape would prove advantageous, and lessen the chance of wedging or binding if a front bearing band of lead be used.

The 9-inch Sutcliffe breech-loading gun is rifled and shotted in exact imitation of the Krupp guns of similar calibre. A few of Gruson's chilled shells, such as Krupp uses, have been procured, and some projectiles have been made here in good imitation of the Krupp. As yet but a dozen rounds have been fired, but I question if the practice will prove equal to that of the expansive system; and Krupp having found "leading" of the rifling to be an irremediable evil when employing lead-coated projectiles, we shall doubtless find the same difficulty here. After two or three rounds from this gun, thin shavings of lead can be scraped off the bore with a knife. Apart from the merits of the breech mechanism, which remains to be tested, I venture to express the conviction, strengthened by observation during the past two years, that when this gun is bored up to a calibre of 10 inches, as is contemplated, if it be rifled on the plan given in either Table III. or X., and chambered and shotted according to either of the plans on Plate XIX., the resulting practice will prove in every respect superior to that of the lead-coated system.

The 8-inch rifle which has recently been tested at Sandy Hook is "converted" from a 10-inch Rodman gun, on the plan of Major Palliser, by the insertion of a coiled and reinforced wrought-iron tube held in position by a muzzle-collar. As will be seen by the report of the Ordnance Board, herewith appended, the proof of this gun is considered eminently satisfactory, and is no less a vindication of the excellence of our improved system of projectiles and rifling than of the merits of the gun itself.

The lining of cast-iron guns with rifled tubes of other material is chiefly valuable, in my opinion, as a system of conversion *per se* which affords us the only practicable means of utilizing our otherwise comparatively worthless smooth-bores; and although in some cases strength may be added, yet the mere gain in strength over a simple cast-iron gun of equal weight and calibre would not, in my opinion, justify the expenditure.* The action of our projectiles has proved so easy upon the soft wrought-iron bore that it is probable we could successfully convert our 10-inch guns by simply introducing, without reboring the gun, a tube of bronze one inch in thickness (say phosphoric bronze, since hardness would be in this case a more essential quality than strength). With a bronze tube the chances of success would be increased by rifling it according to the plan recommended in Table III. of my report, whereby the work of rotation would be distributed to good advantage throughout the bore.† Holland had but partial success in this direction, not from the want of strength in the guns, but from the mashing and scoring of the tubes, resulting from the use of the studded projectile—the same cause which limits the serviceability of the English converted guns to one hundred and eighty rounds, although firing less than half the weight of shot and less than one-third the powder employed in the 8-inch rifle at Sandy Hook, where the use of the double-lipped expansive projectile, as at Fort Monroe, has given unqualified satisfaction, and contributed very materially to the success of the experiment.

The subjoined official report of this trial I will preface with the following brief summary:

The gun to be proven was originally a 10-inch Rodman smooth-bore, manufactured at the South Boston foundry in 1866, and inspected and proved by myself; density of the metal, 7.2722; tenacity, 32,369 pounds per square inch; initial tension, 12,000 pounds; and was converted on the plan of Major Palliser. The tube was manufactured and finished by Sir William Armstrong, and was

* The wrought-iron tube has the merit of lessening the chances of an explosive burst. The steel tube, if of good and homogeneous metal, undoubtedly adds strength to the structure; but for such tubes we should have to rely upon foreign manufacturers. A wrought-iron tube, reinforced, as far as the position of the trunnions, with a light steel jacket, inserted from the muzzle and held in position by a *small* screw passing through the breech, or inserted from the rear, having a shoulder, and secured by a *large* breech-screw, would, I believe, constitute the best available system for the same amount of money, and one within the manufacturing resources of our own country.

† Thus, our old bronze might be utilized, as well as our old guns, and an end put to the pious fraud of citizens who petition Congress for old guns wherewith to erect monuments to the memory of our departed heroes, but who afterwards find it convenient to sell the gift for what it will bring as scrap in the market, and with the proceeds ornament their town squares and cemeteries with cenotaphs of stone.

inserted and rifled at the West Point foundry, N. Y. The "play" of the tube in the cast-iron body of the gun was something over one-hundredth of an inch; thickness of the tube, 2.75 inches.

When thus altered, the gun, which had been previously without preponderance, was heavy at the muzzle, the counter-preponderance at the face of the breech being 450 pounds. This was controlled by temporary expedients. In all future guns of this class this difficulty will probably be remedied by reducing the trunnions from 10 inches, their present diameter, to 8 inches; removing the metal eccentrically, so as to bring forward the axis of the trunnions one inch; then restoring the diameter to 10 inches by applying eccentric wrought-iron rings, so that the axis of the trunnions is again advanced until it passes through the centre of gravity of the gun. Thus, the trunnion beds of the carriage will require no alteration.

The gun was mounted upon a temporary wooden platform, and five rounds were fired, with charges of 20 pounds to 25 pounds of powder, and projectiles of 160 pounds to 173 pounds. This proved insufficient to *set out* the tube, and the bore showed no change.

Seven additional rounds were fired with battering charges of 35 pounds of powder and projectiles of 173 pounds, after which the tube was found to have been set out against the cast-iron walls, and something over, the greatest diameter of the bore being 8.007 inches at the seat of the charge and at the position of maximum pressure.

After thirty-eight additional rounds, thirty of which were with projectiles of 186 lbs., the greatest enlargement was found to be 0.002 inch at the seat of the charge, and 0.003 inch at the seat of the projectile, where the tube was not yet fully set out.

Fourteen rounds were next fired with an experimental projectile of the wedging class, weighing 165 lbs., the use of which, as it gave dissatisfaction, was discontinued. The greatest enlargement during these fourteen rounds was found to be 0.007 inch about the base of projectile and at the position of maximum pressure.

Fifty additional rounds were then fired with the usual battering charge of 35 lbs. and projectiles of 174 lbs., and the additional enlargement was 0.001 inch, at a position 36 to 40 inches from the bottom of the bore, where the tube was not yet set out, its interior diameter at this point being 7.997 inches.

Sixty-three rounds were now fired, fifty with projectiles of 187 lbs., giving no additional enlargement at the seat of the charge or projectile, but setting out the tube about 0.002 inch, a little beyond the axis of the trunnions.

One hundred additional rounds with projectiles of 171 lbs. showed a further enlargement of 0.002 inch at the seat of maximum pressure, about 24 inches from bottom of bore.

One hundred additional rounds, with the same charges and projectiles, produced a further enlargement of 0.003 inch at the position of maximum pressure.

Another series of one hundred rounds caused an additional enlargement of 0.004 inch at the position of maximum pressure.

A further record of forty-seven rounds completed a grand total of five hundred and thirteen rounds, with a maximum enlargement of only 0.018 inch, estimated from the twelfth round; or, deducting the enlargement due to the use of fourteen wedging projectiles, the total enlargement due to four hundred and eighty-four battering charges may be set down at 0.011 inch.

The entire record of five hundred and thirteen rounds was apparently insufficient to "set out" the tube (2.75 inches thick) much in advance of the trunnions, and so slight was the wear of the projectiles in the bore that, except at the position of heavy pressures, the bore shows no appreciable enlargement, while the edges of the grooves remain sharp and well defined throughout.

Before the completion of the record, a number of shots were fired for range, accuracy, etc., and every flight was smooth and perfect beyond criticism. The range at twenty degrees elevation was not ascertained; but the accuracy at a mile was considered highly satisfactory, especially in view of imperfect facilities for laying the gun, muzzle preponderance, unstable platform, etc.

A novel and economical feature in the proof of this gun, was the introduction upon the ground of the necessary facilities for firing the same shot two or more times, as might be required. This was effected by attaching the sabots by a screw-thread (see plates) to the base of the projectile, and procuring a supply of spare sabots. Upon recovering a projectile from the butt, it could at any time be placed in a clamp, a wrench applied, the old sabot removed and a new one screwed on; then cleaning and lacquering the shot, to keep it from rusting in the sea-air, it was as good as new.

This firing completes a record of *over one thousand rounds* with the double-lipped expansive projectile—an ordeal far more severe than any mere *service* record of like extent. The firing embraces several series of experiments with powder, and in many instances excessive weights of shot have been employed. Yet we may fairly consider the record as without a blemish, and as showing for our system of projectiles and rifling a degree of perfection never before attained in the history of rifled cannon.

REPORT OF THE BOARD ON EXPERIMENTAL RIFLED GUNS.

8-INCH RIFLE NO. 1.

REPORT OF THE TRIAL OF AN 8-INCH RIFLE CONVERTED FROM A 10-INCH CAST-IRON SMOOTH-BORE RODMAN GUN BY LINING WITH A COILED WROUGHT-IRON TUBE INSERTED FROM THE MUZZLE.

ORDNANCE OFFICE, WAR DEPARTMENT,
WASHINGTON, October 9, 1874.

SIR: I have the honor to recommend that a Board of Ordnance Officers be convened in the city of New York on the 21st of October, instant, or as soon thereafter as practicable, for the consideration of such ordnance subjects, and the trial of such of the experimental guns prepared under the "act of June 6, 1872," as may be submitted to it by the Chief of Ordnance, to whom its reports shall be made.

The following-named officers are respectfully recommended for detail:

Major *S. Crispin*, Ordnance Department.
Major *T. J. Treadwell*, Ordnance Department.
Major *T. G. Baylor*, Ordnance Department.
Captain *Geo. W. McKee*, Ordnance Department, as Recorder.

Very respectfully, your obedient servant,

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

The Hon. THE SECRETARY OF WAR.

SPECIAL ORDERS No. 221.

WAR DEPARTMENT, ADJUTANT-GENERAL'S OFFICE,
WASHINGTON, October 10, 1874.

(*Extract.*)

. . . .

6. A Board, to consist of

Major *S. Crispin*, Ordnance Department,
Major *T. J. Treadwell*, Ordnance Department,
Major *T. G. Baylor*, Ordnance Department,

and Captain *Geo. W. McKee*, Ordnance Department, as Recorder, is appointed to meet in New York City, N. Y., on the 21st day of October, 1874, or as soon thereafter as practicable, for the considera-

tion of such ordnance subjects, and the trial of such of the experimental guns prepared under the "act of June 6, 1872," as may be submitted to it by the Chief of Ordnance, to whom its reports will be made.

By order of the Secretary of War:

E. D. TOWNSEND,
Adjutant General.

U. S. ORDNANCE AGENCY AND NEW YORK ARSENAL,
NEW YORK CITY, January 9, 1875.

GENERAL: I have the honor to transmit herewith the report of the Board on Experimental Guns, etc., of the trial of the 8-inch converted rifle No. 1, accompanied by the recommendations of the Board.

Very respectfully, your obedient servant,

S. CRISPIN,
Brevet-Colonel U. S. A., Major of Ordnance,
President of the Board.

Brigadier-General S. V. BENÉT,
Chief of Ordnance, U. S. A., Washington, D. C.

The Board on Heavy Rifled Ordnance, instituted by the War Department under the act of Congress of June 6, 1872, for the selection of breech-loading and muzzle-loading rifled ordnance for experiments and tests, recommended, among other experiments, as follows:

That in order to test the system of gun-conversions by lining with wrought-iron or steel tubes (as brought to the notice of the Board in a communication addressed to the Chief of Ordnance by Major S. Crispin, and referred to the Board by the Ordnance Department), four 10-inch smooth-bore Rodman guns be converted to muzzle-loading rifles, using two calibres; two of the guns to have a calibre of not less than 8 inches, and two to have a calibre of not more than 9 inches. And, further, that two of the guns be converted by tubing from the rear, and two by tubing from the front; the character of the metal lining, whether of steel or wrought iron, and the other details of conversion, to be determined by the War Department.

The principal considerations which induced the Board to recommend these tests are found, it is believed, in the following extracts from a communication addressed by Major S. Crispin to the Chief of Ordnance, under date of June 12, 1872:

In recent interviews with some of the members of the permanent Board of Engineers of the United States Army, my attention has been forcibly called to the subject of the utilization of our existing granite casemate sea-coast defences by the replacement of their present smooth-bore armament by the introduction of rifled guns of the highest power which these works, from their capacity, will admit of being applied, and which armament will also be of adequate power for many other positions not needing our heavier calibres of 10-inch and 12-inch rifles. The enormous cost of these

works, and the necessity of their utilization by the introduction of an armament not too bulky for their construction—effective against iron-clads, as at present constructed—to replace their present low power, 8-inch and 10-inch smooth-bores and others, and motives of economy, should lead, in my judgment, to experiments with a view of determining if conversion (already successfully inaugurated in the English service) of our cast-iron smooth-bores to rifles of greatly increased power cannot be satisfactorily made in our service, thus utilizing both guns and casemates.

The recommendations of the Armament Board of 1867, restricting our calibres to 10-inch and 12-inch for rifles, provide only for works of a capacity for their introduction; but as rifled ordnance, at least as low as 8 inches, can be effectually used against iron-clads, this question of utilization of existing works inadequate for our standard calibres receives additional importance. Considering that General Rodman, in his plans for heavy ordnance, contemplated an excess of strength for practical use, and knowing that England has already converted over five hundred 71-cwt. smooth-bores, and has one hundred more now under way at Elswick (*primâ facie* evidence of success), it would seem that we would be warranted in undertaking the experiment of the conversion of a 10-inch smooth-bore Rodman gun into a rifle of a calibre of either, say, 8-inch or 8½-inch, the exact calibre to be determined by a thorough examination and consideration of data, and the formation of a mature judgment as to what should be the maximum bore consistent with a safe and durable converted gun.

The general principles of conversion proposed—the lining of the bore with a tube—it will be remembered, was recommended for 10-inch and 12-inch experimental rifles by the Ordnance Board of 1868.

. . . .

This experiment, preliminary to those proposed by the Board of 1868, to line a 10-inch and 12-inch rifle, would, at a moderate cost, throw considerable light upon this subject, and is another reason for its being undertaken.

The decision of the Board on Heavy Rifled Ordnance, in this regard, having been approved, two 10-inch smooth-bore cast-iron Rodman guns were converted by lining them with wrought-iron coiled tubes, inserted at the muzzle, one to an 8-inch rifle and the other to a 9-inch rifle, and were placed at the disposal of the Board on Experimental Guns, etc., by the Chief of Ordnance, under date of October 22, 1874, and with instructions to fire five hundred rounds, as contemplated by the "Board on Rifling and Venting, etc.," convened under orders of the Department under date of March 29, 1873.

Five hundred and thirteen rounds have been fired from the 8-inch rifle so converted, up to the date of this report, under the supervision of the Board.

GUN.

DESCRIPTION OF THE 8-INCH GUN.—(*Plate* I.)

The gun is essentially composed of two parts, the original 10-inch smooth-bore, bored up to an interior diameter of 13.5 inches, and a lining tube of coiled wrought-iron (welded), the breech of which, to a distance of 32.5 inches, being a double tube—the outer one shrunk on to the inner—the former, however, having the same exterior diameter as the inner tube at the muzzle end.

A screw-collar, *b* (Plate I.), prevents the tube from being thrust forward at the muzzle by the compression of its metal by repeated firings.* The bottom of the tube is closed by a wrought-iron base or cup.

The dimensions of the finished bore of the cast-iron body, and the exterior dimensions of the inserted wrought-iron tube, are given in the accompanying Table No. 3. It will be seen that play between the cast-iron body and the tube does not exceed 0.0105 inch for a length of 32 inches at the breech end, and 0.009 inch for the remainder of its length. The tube was adjusted to the cast-iron body with great care, especially to ensure its breech end being closely in contact with the cast iron. After its insertion, it was secured at the muzzle by the screw-collar above mentioned. The venting is the ordinary copper bushing, the old vent being closed by a wrought-iron screw-plug.

A screw-plug, *c* (Plate I.), is inserted to prevent the tube from turning. The rifling consists of fifteen grooves and lands (equal), with an uniform twist of one turn in forty feet. Additional details will be found in the drawings, Plate I.

The weight of the gun and tube complete is 16,160 pounds.

CARRIAGE.—(*Plate* II.)

The gun is mounted on the ordinary service 10-inch wrought-iron carriage for the service of our 10-inch smooth-bore cannon in casemate. It consists of the upper carriage and chassis, the total weight being about 6,000 pounds. The axis of the gun is 7 feet above the surface of its wooden platform. The upper carriage, consisting of two cheek-pieces connected by its transoms, has attached the box-clamp and friction-plates of the recoil-check. The only changes in its construction are the ones necessitated by the modes adopted for checking recoil and for elevating and depressing the gun.

The following descriptions in addition to Plate II. set forth these changes:

The recoil is checked by friction, using a device illustrated in Plate II. The principle of this check is as follows:

The simple friction of two small plates acting in contact with the upper and lower surfaces of a single broad wrought-iron rail, extending midway between the chassis rails nearly the length of the carriage, combined with the increased resistance afforded by a slight wedge-shape given to the latter, afford the power for absorbing the recoil.

This apparatus is secured, it will be seen, to the front of the chassis by a transom, taking the place and position of the front hurters, and a plate bolted to it on top, between which the friction-

* Or by the reaction of the tube against the bottom of the bore, and the forward *pull* and friction of the projectile on the rifling.—J. G. B.

rail passes, *free to move to the front longitudinally.* Its position with respect to the other parts of the carriage and chassis is clearly shown by the drawings. It is secured at the rear end by a rod attached to a rubber or steel spring. When the recoil of the upper carriage ceases, the strain on the "friction-rail" is at an end, but the elasticity of the "rail" reacts, and if it was rigidly attached at either end a tendency to *buckle* would evidently exist, and destroy it as a recoil check. This was found a serious imperfection in the multi-rail compressor. It will be seen that this defect does not exist in the present arrangement.

The front end of the "rail" is free to move to the front, as it is not rigidly fastened to the front hurter transom of the chassis, and as it has a flexible attachment at the other or near end, afforded by the rubber or steel spring.

The box-clamp, with its friction-plates and screw, is shown by the drawings; also it is shown in position (with all its parts assembled) when the gun is ready for firing. It is believed, it may be stated in this connection, that by employing a simple automatic device to turn the screw through a given arc, commencing to act at the time when the upper carriage is almost into battery, a decided improvement will result; especially will this provide for any neglect of gunners to tighten the clamp before firing, and thus avoid the possibility of the check ever being in a condition not to act when the gun is fired.

For elevating and depressing, two circular-toothed arcs, having their centres at the axis of the trunnions (one on each side), are attached to the gun. A wrought-iron axle passing through the cheek-plates has at one end a hand-wheel. By simple multiplied gearing, power is transmitted to the toothed segments (see Plate II.) This arrangement admits of 20° of elevation and 14° of depression.*

The means for loading and running the gun and carriage in and out of battery and traversing, remain unchanged from the original systems of 10-inch smooth-bore carriages. The ordinary service pintle and strengthened pintle transom (2 inches thick) were used in the experiments.

PLATFORM.†

The details of the wooden platform used are given in Plate VI.

The carriage complete weighs about 6,000 pounds; the upper carriage weighs 2,500 pounds, and the chassis 3,500 pounds.

POWDER.—(*Plate* V.)

The experiments at Fort Monroe during the winter of 1872 and spring of 1873, with what is known as hexagonal-grained powder, manufactured by Messrs. E. I. Du Pont & Co., Wilmington, Del., demonstrated the superiority of this powder for heavy ordnance, giving low maximum pressures and satisfactory velocities, with great uniformity in its action. One of the samples tested,

* It was only used during the last rounds.—*Board.*

† A few heavy timbers judiciously assembled and embedded in the sand. Plate omitted.—J. G. B.

designated by the manufacturers as E. V., was selected as the standard for guns of 8-inch and 9-inch calibres.*

The uniformity in size of grain, and their particular polyhedral shape, ensure great uniformity in the position and size of the numerous interstices in the make-up of the charges, and thus ensure, with an uniformity of density in grain, a high degree of uniformity in pressures and velocities for given charges of powder and weights of projectiles. The above is confirmed, it is believed, by the results shown in Table No. 1 of this report.

The powder used in the experiments was composed of the United States standard proportions for its different ingredients, and had a specific gravity of 1.7511. Its shape, dimensions, and weight of grains are given in Plate V.

The cartridge bags were made allowing a windage of .85 inch, the material used being woollen serge. The friction primers were made at Frankford Arsenal, and proved of excellent quality.

PROJECTILES.—(*Plates* III. *and* IV.)†

The projectiles used in the experiments were elongated cast-iron cored-shot, with soft metal bases, to take the grooves and ensure rotation. Two kinds were employed (Butler and Arrick); see Table No. 1. Their description will be found attached to Plates III. and IV.

It will be seen (Tables Nos. 1 and 2) that four hundred and ninety-seven Butler and sixteen Arrick were fired during the trials.‡ The shapes and general characteristics are shown in Plates III. and IV. The weights used will be found in Table No. 1.

* Fourteen charges, with 100 pounds of E. V. hexagonal-grained powder and 450-pound shot, in the 15-inch gun, gave a mean maximum pressure of 18,964 pounds, and a mean initial velocity of 1,594 feet. Three charges, using 120 pounds E. V. hexagonal-grained powder and 450-pound shot, gave a mean maximum pressure of 22,000 pounds and a mean initial velocity of 1,696 feet. One 450-pound shot, with 125-pound charge, gave a maximum pressure and velocity, the former 22,000 pounds and the latter 1,735 feet. Seven rounds from an 8-inch wrought-iron rifle, with 35-pound charges and an average weight of projectile of 168⅝ pounds, gave a mean maximum pressure of 29,714 pounds and a mean initial velocity of 1,470 feet.—*Board.*

† The "Butler" projectile it is unnecessary to describe. The "Arrick" ["Eureka" ("Stafford")] projectile failed to give satisfaction, and a description of it is deemed unimportant. Plates III. and IV. therefore omitted.—J. G. B.

‡ Firings were suspended with the Arrick projectiles after sixteen rounds; the lot of fifty presented for experiments and tests being judged by the Board, in view of the results obtained with the sixteen rounds fired, as too imperfect to warrant further trials with them. It has since been reported to the Board that the details of this projectile have been modified in some respects, and that the results with it were more satisfactory.—*Board.*

The Butler projectile worked smoothly and uniformly, fully taking the grooves,* and giving general satisfaction.

EXPERIMENTS AND TESTS.

Trials were first made with charges of powder varying from twenty to thirty pounds, and with projectiles varying from one hundred and fifty-seven to one hundred and seventy-three pounds, to note resulting pressures and velocities and the effects on the gun, and were preliminary to the uses of thirty-five-pound charges, the weight selected for the test of the gun for endurance. A record of these firings is given in Table No. 2. Satisfactory results having been attained (see Table No. 2), experiments were then commenced for testing the endurance of the gun, using thirty-five-pound charges. Four hundred and ninety-eight rounds were fired with this charge, and six rounds with a charge of thirty pounds, completing a record of five hundred and four rounds. The results of these firings are given in Table No. 1.

It will be seen that five hundred and thirteen rounds in all have been fired from the gun. The velocities were taken with the Le Boulengé chronograph. The Rodman pressure-plug, placed in the cartridge-bag, was used for ascertaining the maximum pressures. The calculated energy of a mean weight of projectile 173.7 pounds with thirty-five-pound charge shows a power about equal to the wrought-iron 8-inch English service rifle; and, as it was believed that the length of the bore would enable us to advantageously burn but little, if any, more powder, a charge of thirty-five pounds was fixed as a maximum in the tests. The mean maximum pressure with battering charges, it will be seen, was 31,282 pounds. The necessary repairs of proof-butt, the delays in the procurement of projectiles, etc., and the limited and imperfect character of our facilities at command, are causes which prevented an earlier completion of these experiments than December 23, 1874.

The gun was as a rule washed out, star-gauged, and otherwise examined at the end of each day's firing.

ACCURACY.—(*Plate* VIII.)†

Before concluding the series of five hundred and thirteen rounds, it was desired to make some experiments to test the accuracy of the system of rifling and projectiles; accordingly, a board target, twenty by forty feet, was erected

* The majority of these shots were recovered and examined.—*Board.*

† From Table No. 7 a target may be plotted. Plate VIII. is therefore omitted.—J. G. B.

exactly one mile (1,760 yards) from the gun, and commencing with the four hundred and sixty-sixth round, on December 22, 1874, thirteen consecutive shots, using thirty-five-pound charges, were placed in the target, thus concluding the record of that day's firing. The details of this day's firing are given in Table No. 7, and the accompanying target plotting (Plate VIII.) shows the accuracy attained.

Considering the appliances used for training and sighting the gun, and other circumstances attending the trial, this record must be considered highly satisfactory. The remarkably small horizontal deviations afford indisputable evidence of the serviceable condition and good character of the rifling, and of the satisfactory action and accuracy of the projectiles.

EFFECTS ON THE GUN.

The attached table of enlargements (Table No. 4) shows as follows:

After the first five rounds the star-gauging indicated no sensible enlargement of the bore, showing that the play allowed in the construction between the tube and cast-iron body had not yet been obliterated, and that the tube was not yet set out firmly against the cast-iron walls; seven additional rounds, using battering charges, firmly set the tube in its position. The enlargements by subsequent firings are given in the table, and it will be seen that after five hundred and thirteen rounds the maximum increase of bore was 0.040 inch at 22 inches from the bottom.

By deducting the play of the tube at that point we have only an actual maximum enlargement, due to the total five hundred and thirteen rounds, of 0.0295 inch. These results are especially satisfactory, as an official report of European experiments with a converted system (8-inch rifle) gave, in a case brought to the notice of the Board, a maximum enlargement of 0.06 inch, after only one hundred and sixty odd rounds, with projectiles of one hundred and fifty pounds and thirty pounds of powder.

Impressions of the bore taken with gutta-percha (see Plate VII.) show but little erosion from the gases, and this and a slight general roughness at the seat of the shot are the extent of the damage done to the surface of the bore in the entire experiments and tests.*

This absence of erosion is only to be explained by the action of the soft metal base of the projectile, which, before the inertia of the shot is overcome, is

* English official reports state that one hundred and eighty rounds is the greatest number fired from any one gun (eighty-pounder converted) without any injury.—*Board.*

pressed against the lands and fills the grooves, thus diminishing the normal windage to a minimum, and preventing the flow of the gases over the body of the projectile. Erosion is a prominent difficulty to be overcome, using non-expanding systems of projectiles for muzzle-loading rifles ; and whilst their use may reduce the pressure to a slight extent in comparison with the system tried by us, yet the absence of guttering and other deteriorations of the bore ensured by the expanding system, without abnormal or dangerous pressures, is highly satisfactory. The vent shows a maximum enlargement of .24 inch, and a slightly circular guttering exists at the exterior surface of the bushing at the surface of the bore. Some unimportant weld marks are discernible on the bore. In other regards the gun is wholly sound in condition, and is regarded by the Board as perfectly serviceable for any desired additional experiments and tests.

EFFECTS ON CARRIAGE.

During the course of the trials numerous small repairs, such as replacement of bolts, etc., had to be made on the carriage, but no injuries requiring extensive overhauling occurred, and at the end of the trials its condition was one of general serviceability. The "recoil-check" performed its work well, and remained serviceable to the end of the firing. The elevating apparatus worked satisfactorily in its limited use, and may, it is believed, be relied upon for elevating and depressing and to correct the effects of muzzle preponderance. The mean recoil of the upper carriage will be found noted in Table No. 1. The gun was served with the ordinary means and appliances provided for our 8-inch rifles. It was mounted on a wooden platform, covered by a wooden casemate for convenience in conducting the firings.

VELOCITIES AND PRESSURES.

An analysis of the record shows as follows : A mean initial velocity of 1,374 feet, using battering charges of thirty-five pounds of powder, and a shot of one hundred and eighty-six pounds, the mean maximum pressure being 33,583 pounds per square inch, and for a shot of one hundred and seventy-one pounds a velocity of 1,419 feet, and a corresponding mean maximum pressure of 30,126 pounds. Seventy-eight shots of about the weight of the former, and four hundred and five shots of about the weight of the latter, were fired. The mean weight of all projectiles—using thirty-five pound charges—is 173.7 pounds, and the mean velocities and pressures obtained are, respectively, 1,411 feet and 31,300 pounds. The record of firing, from which Table No. 1 was compiled, shows, taking into

consideration variations in the manufacture of different lots of powder, great uniformity in pressures for different weights of projectiles, and a perfectly satisfactory accord between pressures and corresponding initial velocities, giving convincing proof of uniformity in both the action of the powder and projectiles.

STRENGTH OF THE SYSTEM.

The work performed by this system of gun-construction in these experiments and tests, it will be seen from the accompanying records, about equals that attained by the 8-inch nine-ton rifle of the English service. The intention is to secure from our 10-inch smooth-bore system, by conversion, a rifle of at least the power attained in these experiments, and of sufficient strength to guarantee an adequate endurance for the number of rounds which may be deemed necessary the system should stand.

The principal dimensions of the 10-inch smooth-bore gun are a total length of 136.66 inches, a length of bore of 120 inches, a maximum diameter of 32 inches, a thickness at the breech of 16.66 inches, and a diameter at the muzzle of 16.2 inches. As converted on the present plan to an 8-inch rifle (16,160 pounds weight), we have a thickness at the breech of 19 inches, a *thickness of walls* at the maximum diameter of 12 inches, and at the muzzle of 4.1 inches, and a length of bore of 117.25 inches. It closely approximates in these dimensions to the Woolwich 8-inch gun of nine tons. This latter system is evidently one of great strength *per se;* but in the opinion of the Board in this regard it is more than equal to the work required of it, using improved powders giving reduced pressures.

The fact that R. L. G. English powders give maximum pressures of 29.8 tons per square inch, whereas pebble or hexagonal powders reach only a maximum pressure of about fifteen tons per square inch (all these kinds were used in 8-inch rifles, employing the same weight of charge and projectile), shows the important changes which have been made in powders as to pressures, velocities being maintained, and points to the conclusion that gun-constructions lighter in weight and not so strong in material as the English system can be successfully used to obtain the same power and still have an adequate endurance.

The fact that a gun is strong enough to withstand R. L. G. powder or its equivalent is not so important in our land service with heavy ordnance, as there exists no adequate reasons to fear the contingency of the absence, under any circumstances for service with our guns, of supplies of large-grained or hexagonal powders, or powders possessing their characteristics.

The special construction tested, the subject of this report, in the use of bat-

tering charges had to endure maximum strains (repeated) of say 31,300 pounds per square inch at the surface of the bore. This would give a strain of say 11,000 pounds per square inch in a homogeneous structure on that circumference which is now the interior surface of the cast-iron body.

Even making a considerable allowance for the more compressible nature of wrought iron over cast iron, it is fair to presume that the cast-iron body at the surface of its bore had not to endure, in the five hundred and odd rounds fired, at any fire over one-half of its tensile strength (30,000 pounds), and hence the inference is warranted that cast iron is entirely adequate to perform the work which would be required of it in resisting tangential strains in 8-inch converted guns, constructed as the one tested, using a thickness of tube of 2.75 inches.

Another inference to be drawn from these experiments and the above views is that it is probable—with our superior production of cast iron in this country, using the principle of hollow casting and interior cooling, and a strong and judicious mode of lining the gun with either steel or wrought iron—that new constructions applicable to rifles of 10 inches and 12 inches, and even higher calibres, and having the necessary strength and endurance and uniformity of endurance required for all the wants and vicissitudes of our sea-coast service, can be economically secured. Also, if deemed desirable, that our 15-inch guns can probably be converted into durable rifles having a large increase over their present powers.

In this connection it may be noted that it is thought beyond question that built-up gun-constructions (rifles), using either steel or wrought-iron tubes for the interior and cast-iron for the body, are superior in strength (and non-liability to *explosive bursting*) to homogeneous structures composed entirely of cast iron; and hence that the converted systems proposed will have greater endurance and safety than similarly modelled 8-inch cast-iron rifles. It is also believed that built-up gun-constructions, with proper kinds and qualities of metals for the interior tubes and the exterior bodies, have a broader margin of safety, from the separation into parts, in the cases of excessive or long-continued strains, than homogeneous structures made in one solid mass and finished from such masses.

It is inferred from the above considerations and the satisfactory results attained in our trials that a durable rifle of at least 8-inch calibre, to use full battering charges, can be secured by conversion on the plan tested. Whilst expressing confidence in this plan from the results attained, yet the Board deems it important to call attention to the fact that more endurance may be obtained by other systems of conversion, equally as economical, now in course of preparation for test and experiment.

EFFECTS AGAINST ARMOR-PLATES.

The table of comparisons between the 8-inch converted and the English 8-inch nine-ton gun shows that we can calculate on a power from the former equal to that of the latter (see Table No. 5). The calculations are not carried beyond eighteen hundred yards, as at our more important harbor defences a greater range than this would not generally be required for their casemated guns, which would probably be used in case of attack as powerful auxiliaries to the larger calibres of 10-inch and 12-inch rifles. The calculated power against armor-plates (unbacked) is at the muzzle a penetration of 8.66 inches; at six hundred yards, 7.87 inches; at one thousand yards, 7.42 inches; and at eighteen hundred yards 6.75 inches. It is believed that in some of our harbors, where the draught of water is comparatively light, guns of this power would have sufficient energy to afford by themselves an efficient armament. It may be here stated that the nationalities of Europe embrace in their calibres for heavy ordnance as low as 7 inches.

Table No. 6 shows that an increase in power from two to three-fold over the original smooth-bore 10-inch gun, at ranges varying from one thousand to three thousand yards, is gained by the conversion.

RECOMMENDATIONS OF THE BOARD.

The present armament for our sea-coast includes for our casemate defences twelve hundred and ninety-four 10-inch Rodman smooth-bore guns distributed in our harbors, as follows: At Portland, Me.; Boston and New Bedford, Mass.; Newport, R. I.; New York, N. Y.; Fort Delaware, Del.; Hampton Roads, Va.; Charleston and Savannah harbors, the forts of the Gulf, and the harbor of San Francisco, Cal.

These guns are worthless for purposes of defence against armor-plated vessels of modern construction, and the casemates provided for their emplacements (which have cost millions of money) are now useless, and demand for their utilization either a rearmament of new guns, or that the old ones shall be converted into rifles of efficient power, to render the casemate batteries powerful and efficient auxiliaries to our heavier calibres in barbette; all to provide effective harbor defences.

Proof that effective and durable guns can be provided by conversion having been given by our recent experiments, and conversion affording an undoubted economy, it is recommended that the Department ask for liberal appropriations to be made to initiate the work of providing converted rifles for already existing

permanent casemated works now useless, as above stated, for the want of efficient armaments, yet for which appropriations are annually being made.

The strong assurances afforded by our experiments that additional experimental guns of the heaviest calibre now fabricated by civilized nations, constructed on the principle of combining cast-iron with wrought-iron or steel-lining tubes, and after judicious and well-matured plans, approved by the Department, will, when tested, give successful results, and prove that an effective, durable, and economical rifle armament can be secured, leads the Board to submit the additional recommendation that Congress be asked to appropriate an adequate sum for further experiments and tests, and especially for the manufacture, trial, and tests of one 10-inch and one 12-inch experimental rifle, to be constructed in accordance with the general plan above suggested.

S. CRISPIN,
Brevet-Col. U. S. A., Major of Ordnance,
President of Board.
T. J. TREADWELL,
Major of Ordnance.
T. G. BAYLOR,
Major of Ordnance.
GEO. W. McKEE,
Captain of Ordnance,
Recorder of Board.

ORDNANCE OFFICE, January 18, 1875.

Respectfully submitted to the Secretary of War.

S. V. BENÉT,
Brigadier-General,
Chief of Ordnance.

Records of Firings for Endurance with an 8-inch Experimental Rifle from

DESCRIPTION OF GUN.	DATE.	Number of Shots.	CHARGE. Kind of Powder.	CHARGE. Cartridge. Weight.	CHARGE. Cartridge. Height.	CHARGE. Cartridge. Diameter.	PROJECTILE. Kind.	PROJECTILE. Weight.	PROJECTILE. Length.	PROJECTILE. Diameter.
GUN No. 1.	*1874.*			*Lbs.*	*Ins.*	*Ins.*		*Lbs.*	*Ins.*	*Ins.*
A rifle converted from a 10-in. Rodman cast-iron smooth-bore by lining with a jacketed wro'ght-iron coiled tube inserted at the muzzle.	From Oct. 24 to Oct. 28, incl've	2	Du Pont's hexagonal E. V. (1874); density, 1.7511. For further description, see accompanying plate and report.	35	22	7.15	Butler	160.	18	7.95
		9		35	22	7.15	"	173.	18	7.95
		25		35	22	7.15	"	186.	19	7.95
		2		*30	19	7.15	"	186.	19	7.95
	From Oct. 29 to Oct. 30, incl've	3		35	22	7.15	"	186.	19	7.95
		12		35	22	7.15	Arrick	165.	19	7.95
	On Oct. 29 and Nov. 6	4		*30	19	7.15	"	165.	19	7.95
	On Nov. 16	14		35	22	7.15	Butler	174.	18	7.95
Calibre, 8 ins.	On Nov. 17 . . .	37		35	22	7.15	"	173.9	18	7.95
		19		35	22	7.15	"	186.2	19	7.95
Total length of gun, 136.66 ins.	On Nov. 18	31		35	22	7.15	"	187.	19	7.95
	From Nov. 21 to Nov. 27	36		35	22	7.15	"	170.27	18	7.95
Length of bore, 117.25 ins.	On Nov. 27 and Nov. 28	33		35	22	7.15	"	170.6	18	7.95
Length of rifling, 107.25 ins.	From Dec. 1 to Dec. 3, incl've . .	24		35	22	7.15	"	170.2	18	7.95
Diameter of bore, incl'd'g grooves, 8.15 ins.	On Dec. 9 and Dec. 10	50		35	22	7.15	"	170.38	18	7.95
	From Dec. 12 to Dec. 14, incl've	50		35	22	7.15	"	170.25	18	7.95
No. of grooves and lands, 15 each.	From Dec. 15 to Dec. 17, incl've	51		35	22	7.15	"	171.	18	7.95
Twist uniform—1 turn to 40 ft.	On Dec. 18	34		35	22	7.15	"	171.64	18	7.95
Weight of gun, 16,160 lbs.	On Dec. 21 and Dec. 22	36		35	22	7.15	"	171.25	18	7.95
	On Dec. 23	32		35	22	7.15	"	170.	18	7.95
		504								

Board on Experimental Guns, etc., convened under

* These charges are exceptional, and were used for experiments with projectiles, etc.

No. 1.

October 24 to December 23 (inclusive), 1874, at Sandy Hook, New York Harbor.

Mean observed Velocities of the Projectile at 110 feet from the Muzzle of the Gun, as recorded by Le Boulengé's Chronograph.	Velocities at the Muzzle.	ENERGY OF PROJECTILE. Total at the Muzzle. $\frac{PV^2}{2g}$	ENERGY OF PROJECTILE. Per inch of the Shot's Circ'ference. $\frac{PV^2}{2g\,2\pi R}$	Gas Pressure per sq. in. Surface of Bore, as taken with Rodman's Internal Pressure-Gauge.	Recoil of Upper Carriage.	REMARKS.
Ft.	*Ft.*	*Foot-lbs.*	*Foot-lbs.*	*Lbs.*	*Ft.*	
1,449	1,459	5,288,648	211,546	34,225	3.99	Distance of the first wire target from the muzzle of the gun, 60 ft.; distance between first and second targets, 100 ft.
1,423	1,432	5,508,664	220,346	32,278	4.67	
1,357	1,365	5,381,364	215,254	33,833	4.39	
1,296	1,303	...	...	...	...	Mean weight of projectiles, using battering charges (35 lbs.), 173.70 lbs.
1,368	1,376	5,468,446	218,737	32,666	4.4	
1,413	1,422	5,180,806	207,232	33,333	3.53	Mean velocity at muzzle, using battering charges (35 lbs.), 1,411 ft.
1,352	1,361	...	...	...	...	
1,411	1,420	5,448,037	217,921	31,714	4.15	Mean maximum pressure, using battering charges (35 lbs.), 31.282 lbs.
1,402	1,412	5,383,727	215,349	34,000	3.71	Mean energy at muzzle, using battering charges (35 lbs.), 5,369,947 lbs.
1,366	1,375	5,466,372	218,654	34,000	3.85	
1,372	1,380	5,616,969	214,678	33,500	3.51	The maximum velocity at the muzzle, obtained with 35 lbs. of powder and 165-lb. (A.) projectile, 1,422 ft.
1,417	1,426	5,376,396	215,055	30,708	3.73	
1,411	1,420	5,341,581	213,663	28,525	4.12	Maximum velocity at muzzle, with 35 lbs. of powder and 170-lb. (B.) projectile, 1,440 ft.
1,417	1,426	5,374,186	214,967	29,875	2.80	Maximum velocity at muzzle, with 35 lbs. of powder and 174-lb. (B.) projectile, 1,420 ft.
1,396	1,405*	5,222,583	208,903	26,214	3.35	Maximum velocity at muzzle, with 35 lbs. of powder and 187-lb. (B.) projectile, 1,380 ft.
1,385	1,394*	5,137,203	205,488	27,214	3.28	Mean recoil of upper carriage, 3.79 ft. But 200 ft. from muzzle of the gun.
1,386	1,395*	5,159,274	206,370	28,700	3.58	*N.B.*—Four hundred and seventy-nine (479) shots were fired into the butt, distant 200 ft. from the muzzle of the gun; 13 into a target 20×40 ft., at the distance of 1 mile from the gun; and 12 others, for tests of flight over water, etc.
1,400	1,410	5,298,718	211,948	32,625	3.78	
1,435	1,444	5,532,291	221,291	31,500	3.82	
1,431	1,440	5,473,788	218,951	28,166	3.52	

***orders of the War Department, dated October* 10, 1874.**

GEO. W. McKEE,
Captain of Ordnance, Recorder.

* Powder lot No. 18 appears to be not quite up to the standard. The remaining lots tested were Nos. 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20, of fifty barrels each, and comprised the last shipment of five hundred barrels from the works.—J. G. B.

TABLE No. 2.

Record of Firings with an 8-inch Experimental Rifle from October 23 to October 24 (inclusive), 1874, at Sandy Hook, New York Harbor.

Description of Gun.	Date.	Number of Shots.	Charge.				Projectile.				Velocities.	Maximum Pressures per Square Inch at Surface of Bore.	Remarks.
			Kind of Powder.	Cartridge.			Kind.	Weight.	Length.	Diameter.			
				Weight	Height.	Diameter.							
	1874.			Lbs	Ins.	Ins.		Lbs.	Ins.	Ins	Feet.	Lbs.	
GUN No. 1.	Oct. 23	1	Du Pont's hexagonal E. V. (1874). Density, 1.7511.	20	12.6	7.15	Butler	157	18	7.95	Omit'd.	Omit'd.	Distance from muzzle of the gun to the first wire target, 60 feet.
A rifle converted from a 10" Rodman cast-iron	do.	2		20	12.6	7.15	Do.	160	18	7.95	1,015	12,500	
smooth-bore by lining with a jacketed wrought-	do.	3		25	15.8	7.15	Do.	173	18	7.95	1,273	30,000	Distance between wire targets, 100 feet.
iron coiled tube inserted from the front or muzzle.	do.	4		25	15.8	7.15	Do.	173	18	7.95	1,265	35,000	Distance from muzzle of the gun to butt, 200 feet.
Calibre, 8 inches. Total length of gun,	do.	5		25	15.8	7.15	Do.	173	18	7.95	1,237	30,000	
136.66 inches. Length of bore, 117.25	Oct. 24	6		30	19.0	7.15	Do.	160	18	7.95	1,381	32,500	All these shots were fired into the butt, and were preliminary
inches. Length of rifling, 107.25	do.	7		30	19.0	7.15	Do.	160	18	7.95	1,375	36,000	
inches. Diameter of bore, includ-	do.	8		30	19.0	7.15	Do.	173	18	7.95	1,330	27,500	to the 504 rounds fired afterwards to
ing grooves, 8.15 inches. Number of grooves and lands, 15 each. Twist uniform—one turn in 40 feet. Weight of gun, 16,160 pounds.	do.	9		30	19.0	7.15	Do.	173	18	7.95	1,349	36,000	test the endurance of the gun.

Board on Experimental Guns, etc., convened under orders of the War Department dated October 10, 1874.

GEO. W. McKEE, *Captain of Ordnance, Recorder.*

TABLE No. 3.

Relative diameters of Bore of cast-iron body of 10-inch Gun and of wrought-iron Tube for insertion therein, at different points of their cylindrical length.

Inches from Face of Muzzle.	Interior Diameters of Bore.	Exterior Diameters of Tube.	Inches from Face of Muzzle.	Interior Diameters of Bore.	Exterior Diameters of Tube.
118	13.4965	13.4860	76	13.4960	13.4860
117	13.4965	13.4860	74	13.4960	13.4860
116	13.4965	13.4860	72	13.4960	13.4860
115	13.4965	13.4860	70	13.4955	13.4860
114	13.4965	13.4860	68	13.4955	13.4860
113	13.4965	13.4860	66	13.4955	13.4860
112	13.4965	13.4860	64	13.4955	13.4860
111	13.4965	13.4860	62	13.4955	13.4860
110	13.4965	13.4860	60	13.4955	13.4860
109	13.4965	13.4860	58	13.4955	13.4860
108	13.4965	13.4860	56	13.4955	13.4860
107	13.4965	13.4860	54	13.4955	13.4860
106	13.4965	13.4860	52	13.4955	13.4860
105	13.4965	13.4860	50	13.4955	13.4860
104	13.4965	13.4860	48	13.4955	13.4860
103	13.4965	13.4860	46	13.4955	13.4860
102	13.4965	13.4860	44	13.4955	13.4860
101	13.4965	13.4860	42	13.4955	13.4860
100	13.4965	13.4860	40	13.4955	13.4860
99	13.4965	13.4860	38	13.4955	13.4860
98	13.4965	13.4860	36	13.4955	13.4860
97	13.4965	13.4860	34	13.4955	13.4860
96	13.4965	13.4860	32	13.4955	13.4860
95	13 4965	13.4860	30	13.4955	13.4860
94	13.4965	13.4860	28	13.4955	13.4860
93	13.4965	13.4860	26	13.4955	13.4860
92	13.4965	13.4860	24	13.4955	13.4860
91	13.4965	13.4860	22	13.4955	13.4860
90	13.4965	13.4860	20	13.4955	13.4860
89	13.4965	13.4860	18	13.4955	13.4860
88	13.4965	13.4860	16	13.4955	13.4860
87	13.4965	13.4860	14	13.4955	13.4860
86	13.4960	13.4860	12	13.4955	13.4860
85	13.4960	13.4860	10	13.4955	13.4860
84	13.4960	13.4860	8	13.4955	13.4860
83	13.4960	13.4860	6	13.4955	13.4860
82	13.4960	13.4860	4	13.4955	13.4860
81	13.4960	13.4860	2	13.4955	13.4860
80	13.4960	13.4860	1	13.4955	13.4860
78	13.4960	13.4860			

JOHN G. BUTLER, *Captain of Ordnance.*

Board on Experimental Guns, etc., convened under orders of the War Department dated Oct. 10, 1874.

GEO. W. McKEE, *Captain of Ordnance, Recorder.*

TABLE No. 4.

Table of Enlargements of 8-inch Converted Rifle No. 1.

Inches from Bottom of Bore.	Original Play of Tube.	Original Diameter of Bore.	Enlargement after Five Charges of 20 to 35 lbs.	A. Enlargement after 12 Rounds, Seven Battering Charges.	ENLARGEMENTS FROM COLUMN "A" (after "setting up" of Tube). After a Total of 100 Rounds.	After a Total of 208 Rounds.	After a Total of 310 Rounds.	After a Total of 411 Rounds.	After a Total of 518 Rounds.	Total Enlargement after 518 rounds, including the "Set Up" of Tube
11	0.0105	7.985	No enlargement of bore. Tube not "set out."	0.022	0.005	0.005	0.005	0.005	0.005	0.027
13	0.0105	7.985		0.020	0.005	0.005	0.005	0.005	0.005	0.025
16	0.0105	7.985		0.019	0.004	0.004	0.004	0.004	0.005	0.024
19	0.0105	7.985		0.019	0.006	0.006	0.006	0.007	0.008	0.027
22	0.0105	7.985		0.022	0.006	0.006	0.007	0.011	0.018	0.040
25	0.0105	7.985		0.020	0.007	0.008	0.009	0.012	0.016	0.036
28	0.0105	7.985		0.017	0.008	0.009	0.010	0.013	0.015	0.032
31	0.0105	7.985		0.013	0.009	0.010	0.011	0.013	0.015	0.028
34	0.0100	7.985		0.009	0.006	0.007	0.008	0.010	0.011	0.020
37	0.0100	7.985		0.007	0.004	0.004	0.005	0.007	0.008	0.015
40	0.0100	7.985		0.003	0.003	0.003	0.005	0.006	0.007	0.010
45	0.0100	7.985		0.002	0.002	0.002	0.003	0.004	0.005	0.007
50	0.0095	7.985		0.002	0.002	0.002	0.002	0.003	0.004	0.006
55	0.0095	7.985		0.001	0.001	0.001	0.001	0.002	0.003	0.004
60	0.0095	7.985		0.001	0.001	0.001	0.001	0.001	0.002	0.003
65	0.0095	7.985		0.001	0.000	0.000	0.000	0.001	0.002	0.003
70	0.0095	7.985		0.000	0.000	0.000	0.000	0.000	0.002	0.002
80	0.0095	7.985		0.000	0.000	0.000	0.000	0.000	0.001	0.001
90	0.0095	7.985		0.000	0.000	0.000	0.000	0.000	0.001	0.001
100	0.0095	7.985		0.000	0.000	0.000	0.000	0.000	0.001	0.001
117	0.0095	7.985		0.000	0.000	0.000	0.000	0.000	0.001	0.001

Board on Experimental Guns, etc., convened under orders of the War Department dated October **10, 1874.**

GEO. W. McKEE, *Captain of Ordnance, Recorder.*

TABLE No. 5.

Showing the Relative Energies of the 8-inch U. S. R. M. L. (converted) and the 8-inch English R. M. L. of 9 Tons at distances up to 1,800 Yards.

Range.	8-inch R. M. L. of 9 Tons (20,160 lbs.); Charge, 35 lbs.; Projectile, 180 lbs.*			8-inch U. S. R. M. L. Converted—16,160 lbs.; Charge, 35 lbs.; Projectile, 186.5 lbs.			REMARKS.
	Velocity.	Total Energy.	Energy per inch of Shot's Circumference.	Velocity.	Total Energy.	Energy per inch of Shot's Circumference	
Yards.	Feet.	Foot-tons.	Foot-tons.	Feet.	Foot-tons.	Foot-tons.	
0	1,413	2,492	100.2	1,374	2,441	97.7	Seventy-eight rounds were fired with the 186.5-lb. projectile.
200	1,369	2,339	94.0	1,333	2,297	91.9	
400	1,327	2,198	88.3	1,295	2,123	85.0	
600	1,286	2,064	83.0	1,259	1,980	79.2	
800	1,248	1,944	78.1	1,224	1,957	78.3	
1,000	1,213	1,837	73.8	1,192	1,837	73.5	
1,200	1,180	1,738	69.9	1,161	1,742	69.7	
1,400	1,150	1,651	66.3	1,132	1,657	66.3	
1,600	1,122	1,571	63.2	1,104	1,576	63.1	
1,800	1,097	1,502	60.4	1,077	1,499	60.0	

Board on Experimental Guns, etc., convened under orders of the War Department dated October 10, 1874.

GEO. W. McKEE, *Captain of Ordnance, Recorder*

* Compiled from English Tables.

TABLE No. 6.

Relative Effectiveness of a 10-inch Smooth-bore, and the same gun converted into an 8-inch Rifle.

GUN.		Weight of Shot.	Velocity at Muzzle.	Energy at Muzzle.	Penetration in Backed Armor Plates.	FOOT-TONS PER INCH OF SHOT'S CIRCUMFERENCE.				Relative Accuracy at 1,000 Yds	Relative Capacity of sh'l for b'rst-ing charge.
Kind.	Calibre.					At Muzzle.	At 1,000 Yds	At 2,000 Yds	At 3,000 Yds		
	Inches.	Pounds.	Feet.	Foot-tons.	Inches.						
Smooth-bore	10	127	1,600	2,255	7.30	73	36	20	14	1	1
Rifle	8	187	1,375	2,444	8.45	98	74	60	49	3	2

Board on Experimental Guns, etc., convened under orders of the War Department dated October 10, 1874.

GEO. W. McKEE, *Captain of Ordnance, Recorder.*

TABLE No. 7.

Record of Target-Firing with 8-inch Converted Rifle No. 1 at Sandy Hook, New York Harbor, December 22, 1874. Distance of Target from Muzzle of Gun, One Mile.

No. of Fire.	Powder.		Projectile.		Elevation.	Deviation from Centre of Target.				Deviation from Centre of Impact.			
	Kind.	Weight.	Kind.	Weight.		Right.	Left.	Above.	Below.	Right.	Left.	Above.	Below.
						Yards.	Yards.	Yards.	Yards.	Yards.	Yards.	Yards.	Yards.
466	Du Pont's Hexagonal.	35	Butler.	171	3° 0′	. . .	0.25	2.50	. . .	0.39	. . .	1.88	. . .
467		35	Do.	170	2° 55′	. . .	0.33	1.16	. . .	0.30	. . .	0.55	. . .
468		35	Do.	171	2° 55′	0.00	0.00	. . .	0.92	0.63	. . .	. . .	1.50
469		35	Do.	170	2° 55′	0.25	. . .	2.61	. . .	0.88	. . .	2.03	. . .
470		35	Do.	170	2° 55′	. . .	0.83	. . .	0.94	. . .	0.14	. . .	1.53
471		35	Do.	170	2° 55′	. . .	3.05	3.28	. . .	. . .	2.42	2.70	. . .
472		35	Do.	170	2° 55′	. . .	1.11	. . .	3.00	. . .	0.47	. . .	3.58
473		35	Do.	170	2° 55′	0.11	. . .	0.83	. . .	0.35	. . .	0.20	. . .
474		35	Do.	170	2° 55′	. . .	0.22	. . .	3.16	0.42	. . .	. . .	3.75
475		35	Do.	170	2° 55′	0.00	0.00	1.33	. . .	0.63	. . .	0.75	. . .
476		35	Do.	170	2° 55′	. . . . Fired into sand-butt							
477		35	Do.	170	2° 55′	. . .	0.33	3.08	. . .	0.30	. . .	2.50	. . .
478		35	Do.	170	2° 55′	. . .	0.83	. . .	0.86	. . .	0.14	. . .	1.44
479		35	Do.	170	2° 55′	. . .	1.83	1.66	. . .	. . .	1.20	1.08	. . .

REMARKS.

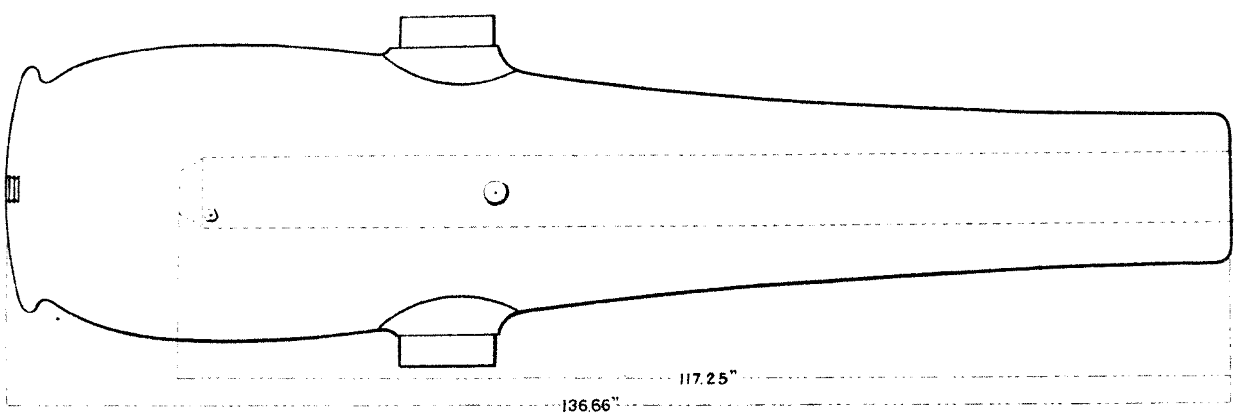
Sound of Projectile in Flight, ... Clear and smooth.
Weight of Projectile, ... 170 pounds.
Strength and Direction of Wind, ... Fresh, front and left.
Weather Thermometer, ... 38 degrees.
‘ Barometer, ... Low.
“ Atmosphere, ... Damp.
Gun—8-inch rifle, No. 1, converted.
Carriage—10-inch wrought-iron Barbette.
Axis of Gun above Plane on which Projectile strikes, 7 feet.

SUMMARY.

Distance of Target, . . . One mile (1,760 yards), (1,609 metres).
Dimensions of Target, ... 7 × 13 yards.
Total No. of Shots fired at Target, ... Thirteen.
Total No. of Direct Hits, ... Thirteen.
Total No. of Ricochet Hits, ... None.
Total No. of Misses, ... None.
Mean Horizontal Deviation from Cen. of Im., . 0.66 yard.
Mean Vertical Deviation, “ “ . 1.80 “
Mean Deviation, “ “ . 1.91 “

10 INCH RODMAN S.B. GUN
CONVERTED INTO AN 8 INCH M.L. RIFLE.

Fig. 1.



Rifling

Twist uniform, one turn in 40 feet.
15 Grooves and Lands, each 0.83772" wide.
Grooves 0.075" deep.
Weight 16160 lbs.

Fig. 2.

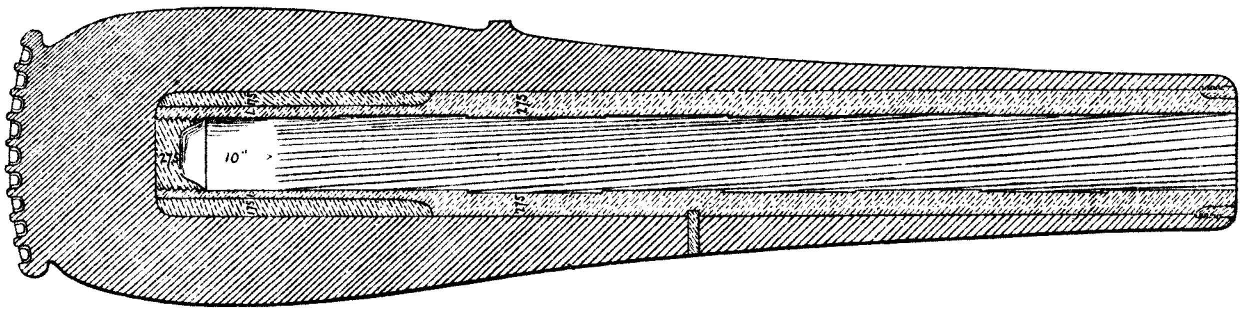


Fig. 4.

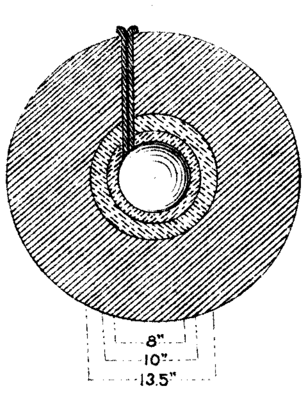


Fig. 3.

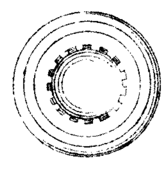
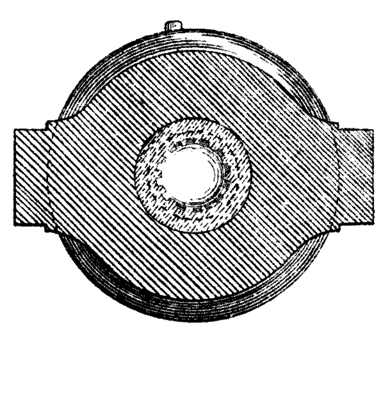
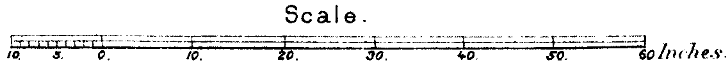


Fig. 5.



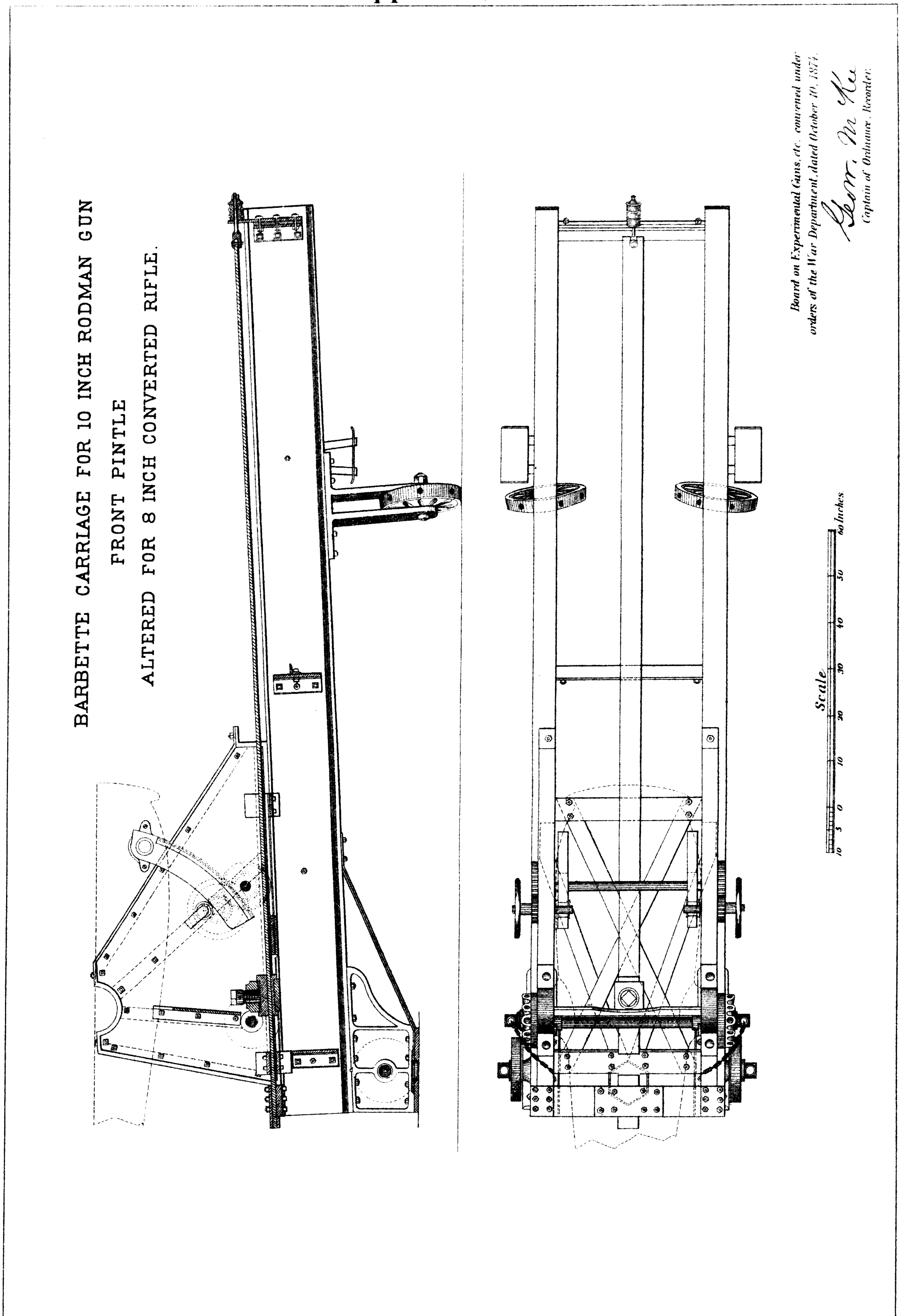
Scale.



Board on Experimental Guns, etc. convened under orders of the War Department, dated October 10, 1874.

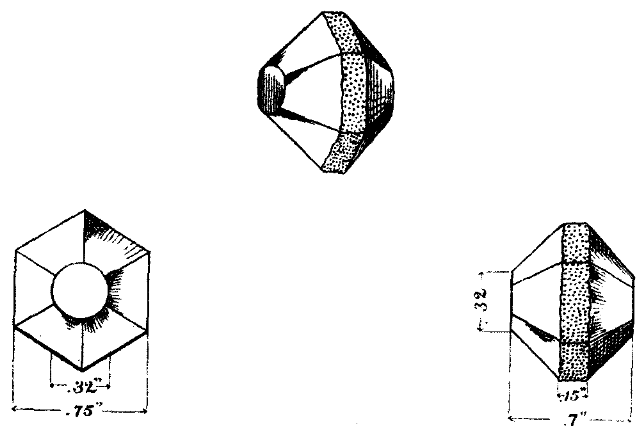
Geo. W. McKee
Captain of Ordnance, Recorder.

D. Van Nostrand, Publisher. New York.



D. Van Nostrand, Publisher. New York.

HEXAGONAL GRAINED POWDER.



Note.

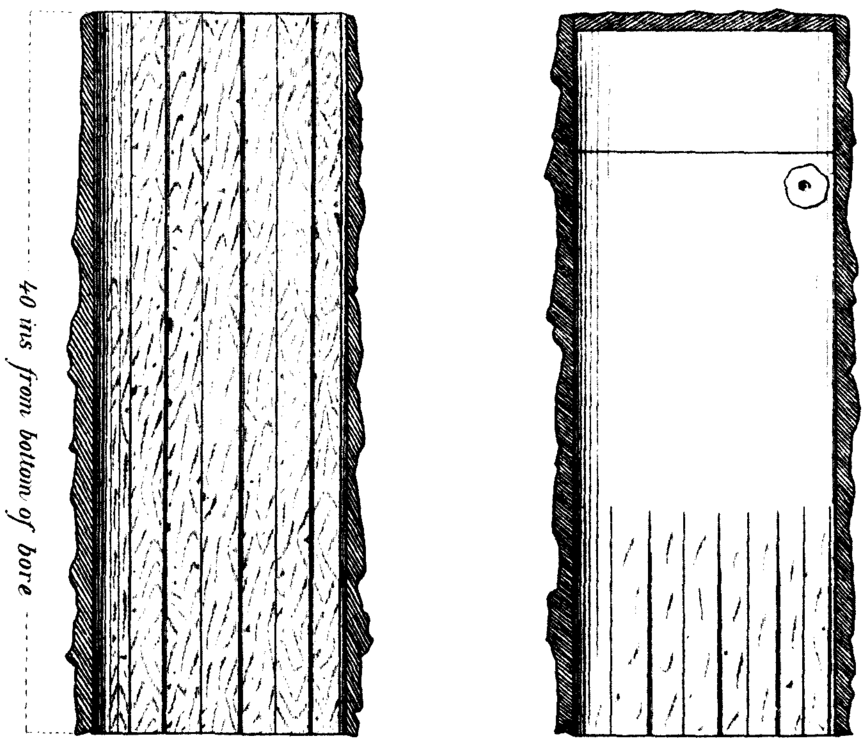
Weight: 80 Grains to 1 lb.
Density; 1.7511

Board on Experimental Guns, etc. convened under orders of the War Department, dated October 10, 1874.

Geo. W. McKee
Captain of Ordnance, Recorder.

SKETCH

ILLUSTRATING THE GENERAL CHARACTER OF EROSION OF BORE AT THE SEAT OF THE SHOT



AFTER 513 ROUNDS

SECTION OF BORE SECTION THROUGH VENT

D.Van Nostrand, Publisher. New York.

REPORT OF THE CHIEF OF ORDNANCE, U. S. A.,

RELATIVE TO HEAVY RIFLES.

ORDNANCE OFFICE, WAR DEPARTMENT,
December 14, 1874.

SIR: I have the honor to submit for the action of the Secretary of War the following:

I. In my annual report, submitted in October last, I expressed the belief that, prior to the meeting of Congress, such valuable information would be obtained from experiments with certain experimental guns, then nearly ready for trial, as would enable this Bureau to report understandingly on that most important subject, the "armament of our fortifications." Although the information is not as complete as was expected, sufficient has been done and reported upon which to base the following recommendations.

There are at present in our forts the following heavy guns:

321—15-inch Rodman guns, smooth-bore.
1,294—10-inch Rodman guns, smooth-bore.
90—8-inch Parrott rifles.
40—10-inch Parrott rifles.

These Parrott rifles, even if reliable when using the heavy battering charges required in modern warfare (of which doubts are entertained), are so few in number as to constitute but an unimportant item among the 4,181 guns required for our forts, when ready for their armament. Rifle-guns ranging from 8 inches to 12 inches in calibre, with power sufficient to penetrate at considerable distances the armor of iron-clad vessels, must be provided. The heaviest rifles are the guns of the present, as they will be of the future; and while smooth-bores may for some time to come play a secondary part, for want of a more powerful weapon, they must inevitably yield to the rifle in every important juncture, as the old smooth-bore musket has given place to the breech-loading rifle in the hands of the soldier. While thus expressing the conviction that the days of smooth-bore ordnance are passing away, I desire to call attention to the fact that the first grand stride toward the introduction of great guns in any service was made in this country by the late General Rodman, of the Ordnance Department, whose reputation as an ordnance officer is world-wide; and that the 15-inch gun he first made in 1861 was the most powerful weapon then known, soon to be surpassed by his 20-inch smooth-bore, made in 1864, weighing

116,000 pounds, and throwing a shot weighing 1,080 pounds. The introduction of iron-clads in modern warfare calls, however, for the penetrating power of heavy rifles; and the smashing and racking effect of a 15-inch smooth-bore must yield to the working energy of a 12-inch rifle that will pierce the thickest iron armor at long distances.

How best and most economically to provide for this great want has exercised the brain and skill of the most distinguished officers in every country, and caused the expenditure of millions of money. There is little doubt that steel is the best material for guns, but the product is by far too costly to be considered now, and, besides, would have to be procured abroad. Wrought-iron guns lined with steel, as adopted by England, have not given that satisfaction that would justify an expenditure of several millions of money in plant for their manufacture. In this country the success of the Ordnance Department in improving the quality of our cast iron for cannon has been marked and satisfactory, and we may lay claim, with good reason, to the best cast-iron guns in the world. They require, however, to be strengthened when subjected to the enormous strains which as rifles they are to withstand; and the success abroad of lining cast iron with wrought iron or steel has suggested an easy and economical mode of converting our cheap cast-iron smooth-bores into powerful and efficient rifles. Our trial thus far with a 10-inch Rodman gun, lined with wrought iron and converted into an 8-inch rifle, gives promise of success; and another lined with steel, now nearly ready for firing, may probably give equal, if not better, results. This 8-inch rifle has already been fired 328 rounds,* with battering charges of 35 pounds of powder and 174-pound shot, giving an average velocity of about 1,425 feet, and a working energy of over 5,000,000 foot-pounds; capable of penetrating seven inches of iron armor at distances from 500 to 1,000 yards. This success enables us at comparatively small cost to utilize the 1,294 10-inch smooth-bore guns, which as smooth-bores are utterly useless against iron-clads, by converting them into 8-inch rifles capable of penetrating 7 inches of iron armor.

The value and interest of this proposed conversion is all the greater from the fact that the casemates of our forts, designed many years since, are too contracted to accommodate a gun of much larger size than the 10-inch Rodman; and this very gun, intended for that special purpose, can thus be strengthened and increased in power to meet the greater demands that modern improvements in naval attack and defence make upon it.

* Up to date, December 19, this gun has been fired 448 rounds.

In again urging upon Congress the absolute necessity for some action that will enable us to place our forts in fighting condition, by providing their armament, I will be excused for stating an undeniable fact, which appears to be entirely ignored: that a fort is worse than useless without guns to arm it; indeed, that it is not a fort at all without its armament—more like a body without a soul; and that other fact, which also seems to be lost sight of: that cannon cannot be purchased ready-made in market, but have to be manufactured specially, and must be provided in time of peace. It is certainly the part of wisdom to be prepared for future wars, that occur in the life of every nation; but should our appeals be constantly disregarded, and the next war find the country unprepared and our sea-coast defenceless and at the mercy of an enterprising enemy, the responsibility for all subsequent disasters cannot rest on the Ordnance Department of the Army, nor on the Secretary of War, nor the Executive.

I have, therefore, the honor to recommend that an appropriation of $250,000 be made by Congress for converting smooth-bore guns into rifles by lining with wrought iron or steel.

The above sum will enable us to convert at least 140 guns.

II. In 1872 Congress appropriated $270,000 "for experiments and tests of heavy rifled ordnance." The guns "designated by a board of officers appointed by the Secretary of War," under the provisions of the act, have been in preparation under the supervision of their respective inventors, and the whole number will probably be ready for trial in the early spring. The necessity and convenience of having a proving and experimental ground in near proximity to the city of New York has forced the Department, with your approval, to establish a temporary one on the Government reservation at Sandy Hook, New York Harbor.

Even in the trial of the 8-inch rifle, referred to above, this Department has been hampered by the want of funds; and these important experiments, that will eventually lead to a determination of the question so vital to the national defence, have had to be conducted under great embarrassments and with the rudest appliances and conveniences.

It is expected that by the opening of spring eight guns, varying in calibre from 8 inches to 12 inches, and in weight from 16,000 to 85,000 pounds, will be ready for firing. The firing of a 12-inch rifle is a very expensive business, each round fired costing about $100. As the gun may stand 500 rounds, its trial will cost $50,000, and only in a less degree will the expense be in the trial of guns of smaller calibre.

Funds necessary for this purpose should be appropriated; and, added to

this, a sum sufficient to provide all the carriages, depressing and others, butts and platforms, and all the appliances, conveniences, and labor required for the prosecution of such exact and important work.

I know of no military or naval power that has not provided an experimental and proving ground, with every facility for conducting trials upon a grand scale; and there is no way of avoiding considerable expenditure, while seeking and obtaining the necessary data from which to draw conclusions that will lead to such large expenditures in the future in arming our fortifications.

I have, therefore, the honor to recommend that an appropriation of $250,000 be made for proving-ground and experiments and tests of heavy ordnance.

Very respectfully, your obedient servant,

S. V. BENÉT,

Brigadier-General, Chief of Ordnance.

The Hon. SECRETARY OF WAR.

DECEMBER 24, 1874.

The gun up to this date has been fired 513 times, 500 of which with battering charges. After the most careful examination and measurements, no damage to the rifling or enlargement of the bore can be detected, and the gun apparently is in perfect order—serviceable in every respect.

S. V. B.

MESSAGE

FROM THE

PRESIDENT OF THE UNITED STATES,

Relating to the condition of the armament of our fortifications, and the necessity for immediate provision by Congress for the procurement of heavy cannon.

To the Senate and House of Representatives:

In my annual message of December 1, 1873, while inviting general attention to all the recommendations made by the Secretary of War, your special consideration was invited to "the importance of preparing for war in time of peace by providing proper armament for our sea-coast defences. Proper armament is of vastly more importance than fortifications. The latter can be supplied very speedily for temporary purposes when needed; the former cannot."

These views gain increased strength and pertinence as the years roll by, and I have now again the honor to call special attention to the condition of the "armament of our fortifications," and the absolute necessity for immediate provision by Congress for the procurement of heavy cannon. The large expenditures required to supply the number of guns for our forts is the strongest argument that can be adduced for a liberal annual appropriation for their gradual accumulation. In time of war such preparations cannot be made; cannon cannot be purchased in open market, nor manufactured at short notice; they must be the product of years of experience and labor.

I herewith enclose copies of a report of the Chief of Ordnance and of a board of ordnance officers on the trial of an 8-inch rifle converted from a 10-inch smooth-bore, which shows very conclusively an economical means of utilizing these useless smooth-bores, and making them into 8-inch rifles capable of piercing 7 inches of iron. The 1,294 10-inch Rodman guns should, in my opinion, be so utilized, and the appropriation requested by the Chief of Ordnance of $250,000 to commence these conversions is urgently recommended.

While convinced of the economy and necessity of these conversions, the determination of the best and most economical method of providing guns of still larger calibre should no longer be delayed. The experience of other nations, based on the new conditions of defence brought prominently forward by the introduction of iron-clads into every navy afloat, demands heavier metal and

rifle-guns of not less than 12 inches in calibre. These enormous masses, hurling a shot of 700 pounds, can alone meet many of the requirements of the national defences. They must be provided, and experiments on a large scale can alone give the data necessary for the determination of the question. A suitable proving-ground, with all the facilities and conveniences referred to by the Chief of Ordnance, with a liberal annual appropriation, is an undoubted necessity. The guns now ready for trial cannot be experimented with without funds, and the estimate of $250,000 for the purpose is deemed reasonable, and is strongly recommended.

The constant appeals for legislation on the "armament of fortifications" ought no longer to be disregarded, if Congress desires in peace to prepare the important material without which future wars must inevitably lead to disaster.

This subject is submitted with the hope that the consideration it deserves may be given it at the present session.

U. S. Grant.

Executive Mansion, January 20, 1875.

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